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MEĐUREDNA KULTIVACIJA – AGROTEHNIČKA MERA ZA POVEĆANJE PRINOSA SOJE

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Sažetak: U cilju proučavanja uticaja međuredne kultivacije na prinos semena soje postavljen je ogled na parceli Poljoprivredne škole u Bačkoj Topoli u periodu od 2015. do 2017. godine. U ogledu su korišćene sorte soje selekcionisane u Institutu za ratarstvo i povrtarstvo u Novom Sadu: Galina, Sava i Rubin. U ogledu su bile zastupljene sledeće varijante međuredne kultivacije: kontrola – bez međuredne kultivacije, jedna, dve i tri međuredne kultivacije useva soje. Prosečni prinos soje se povećao sa povećanjem broja prohoda međurednim kultivatorom u toku vegetacionog perioda soje. Rezultati istraživanja su pokazali da je na varijanti sa jednom međurednom kultivacijom povećanje prinosa iznosilo 5,33%, sa dve međuredne kultivacije 7,10%, a sa tri 7,33%. U godinama sa manjom količinom padavina, značaj međuredne kultivacije bio je mnogo veći. U 2017. godini ostvaren je veći prinos zrna soje za 10,33–13,62% u odnosu na kontrolnu varijantu (bez međuredne kultivacije), a u 2016. godini za 3,09–4,27%. Povećanje prinosa posledica je, između ostalog, smanjene evaporacije zemljišne vlage i sprečavanja poniranja vode u dublje slojeve. Ovo omogućava bolje čuvanje vode u zemljištu u kritičnim periodima tokom letnjih meseci, a takođe i povećava aktivnost mikroorganizama kao i intenzivniju mineralizaciju organske materije, što u krajnoj meri utiče na povećanje prinosa.

Ključne reči: međuredna kultivacija, prinos, soja, sorta.

Uvod

Soja *Glycine max* (L.) Merr., syn *Glycine hispida* (Moench) Maxim. je jednogodišnja samooplodna biljka iz familije *Fabaceae*, potfamilije Faboidae *(Papilionoidae)*, roda *Glycine* (Takhtajan, 2009). U istraživanjima su pronađeni

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drevni kineski spisi koji pokazuju da je soja gajena i visokovrednovana kao hrana, vekovima pre pisanih podataka. Prvi pisani podaci nalaze se u knjizi „Materia medica” cara Šeng Nunga iz 2838. godine pre nove ere (Morse et al., 1949*)*. Od tada, soja je više puta pomenuta u kasnijim zapisima kao najvažnija gajena biljka iz porodice mahunarki, u celoj jugoistočnoj Aziji, posebno u Kini. Kineski poljoprivrednici je ubrajaju u grupu pet svetih zrna, koja osim soje uključuje i pirinač, pšenicu, proso i ječam (Gutschy, 1950). Na našim prostorima ova biljna vrsta je poznata od 19. veka, a veći značaj u gajenju i preradi dobija tek sedamdesetih godina 20. veka. Usled nedostatka domaćih sorti u ovom periodu uglavnom su se gajile introdukovane sorte sa prostora Sjedinjenih Američkih Država (Hrustić i Miladinović, 2011). Najveći proizvođač soje danas su Sjedinjene Američke Države (oko 40% svetske proizvodnje), što zajedno sa Brazilom i Argentinom čini preko 80% svetske proizvodnje. U grupu najvećih proizvođača ubrajaju se još i Kina i Indija. Najveće površine pod sojom u Evropi su u Rusiji, zatim u Ukrajini, Rumuniji, Italiji i Srbiji.

Poljoprivredna proizvodnja predstavlja „fabriku na otvorenom” pri čemu vremenski uslovi često imaju odlučujući uticaj na visinu prinosa (Kvaternjak, 2008). Pored vremenskih uslova, na visinu prinosa utiče i izbor sorte, kao i primenjene agrotehničke mere. Sve agrotehničke mere moraju biti kvalitetno i pravovremeno obavljene (Đukić et al., 2018). Nijedna naredna agrotehnička mera ne može nadoknaditi propuste nastale pri primeni prethodne agrotehničke mere.

Shodno tome, cilj istraživanja je bio da se utvrdi uticaj međuredne kultivacije na prinos zrna soje.

Materijal i metode

U cilju proučavanja uticaja međuredne kultivacije na prinos semena soje postavljen je ogled na parceli Poljoprivredne škole u Bačkoj Topoli u periodu od 2015. do 2017. godine. U ogledu su korišćene sorte soje selekcionisane u Institutu za ratarstvo i povrtarstvo u Novom Sadu, različite dužine vegetacionog perioda: Galina – srednjerana sorta (0 grupe zrenja), Sava, srednjestasna sorta (I grupe zrenja) i Rubin, srednjekasna sorta soje (II grupe zrenja).

Ogled je bio postavljen po dizajnu podeljenih parcela, u četiri ponavljanja, gde su velike parcele bile sorte, a potparcele sa četiri varijante: kontrola (bez međuredne kultivacije), jedna, dve i tri međuredne kultivacije useva soje. Veličina osnovne parcele bila je 15 m^2 (šest redova soje sa međurednim rastojanjem od 50 cm i pet metara dužine).

Predusev u sve četiri godine istraživanja bio je kukuruz, a sa osnovnom obradom nisu unošena u zemljište đubriva. Sa predsetvenom pripremom u zemljište je unet azot (130 kg ha^{-1} amonijum nitrata sa 33,5% N). Neposredno pre setve seme je inokulisano mikrobiološkim preparatom NS Nitragin, na bazi azotofiksirajućih bakterija iz roda *Bradyrhizobium*. Međuredna kultivacija vršena je na dubini od 3–5 cm. U sve četiri godine istraživanja primenjena je standardna agrotehnika za proizvodnju soje, setva na dubinu 4–5 cm, primena herbicida za uskolisne i širokolisne korove, po potrebi zaštita od grinja (2015. godine).

U fazi fiziološke zrelosti ubirane su biljke iz četiri srednja reda iz svake osnovne parcelice (prvi i šesti red su bili izolacija). Biljke su pažljivo vezane u snopove i svaki snop je bio obeležen. Ukupno je bilo 48 snopova. Snopovi su prevezeni na Odeljenje za soju Instituta za ratarstvo i povrtarstvo gde su ovršene. Obračunska parcela je bila 10 m^2. Na osnovu prinosa sa svake parcele (10 m^2) obračunat je prinos po jedinici površine (kg ha^{-1}) i sveden na 14% vlage.

Rezultati istraživanja analizirani su primenom trofaktorijalne analize varijanse upotrebom programa „STATISTICA 10”, a značajnost razlike utvrđena je upotrebom LSD testa.

Meteorološki podaci

Srednje temperature za vegetacioni period soje su bile više u sve tri godine ispitivanja u odnosu na višegodišnji prosek. U 2015. godini zabeležene su najviše temperature, za 1,7°C veće u odnosu na višegodišnji prosek. Meseci jul i avgust su u navedenoj godini bili sa višim temperaturama za 3,2°C, odnosno 3,3°C, a u 2017. godini za 2,2°C, odnosno 3,6°C u odnosu na višegodišnji prosek, što je uz nedostatak padavina predstavljalo ključni faktor za ubrzano sazrevanje i smanjeni prinos zrna soje (tabela 1).

Tabela 1. Prosečne mesečne temperature i sume padavina tokom vegetacionog perioda soje.
Table 1. Average monthly temperatures and sums of precipitation during the soybean vegetation period.

Mesec/ *Month*	Srednje mesečne temperature (°C) *Average monthly temperatures (°C)*				Padavine (mm) *Precipitation (mm)*			
	2015	2016	2017	Prosek/*Average* 1964–2014	2015	2016	2017	Prosek/*Average* 1964–2014
IV	12,0	14,2	11,1	11,7	15,9	74,5	58,0	47,5
V	18,0	16,9	17,6	17,0	191,7	85,0	82,9	64,6
VI	20,7	21,7	22,9	20,0	26,7	143,2	65,7	87,7
VII	24,9	22,8	23,9	21,7	2,6	68,4	12,0	68,7
VIII	24,5	21,1	24,8	21,2	99,7	45,8	17,4	58,5
IX	18,7	18,5	18,1	16,9	52,6	33,7	82,0	47,7
Prosek/Suma *Average/Sum*	19,8	19,2	19,4	18,1	389,2	450,6	318,0	374,7

Veća količina padavina tokom vegetacionog perioda soje bila je zabeležena u 2015. i 2016. godini (389,2 mm i 450,6 mm) u odnosu na višegodišnji prosek

(374,7 mm), dok je u 2017. godini zabeležena najmanja količina padavina (318,0 mm), sa veoma izraženim nedostatkom padavina u julu i avgustu. Najpovoljniji raspored padavina konstatovan je u 2016. godini, dok 2015. i 2017. godinu karakteriše nepovoljan raspored padavina, sa većom količinom u početnim fazama razvića soje i izraženim nedostatkom u fenofazama cvetanja, formiranja mahuna i nalivanja zrna (jun, jul i početak avgusta u 2015. godini i druga polovina juna, jul i avgust u 2017. godini). Ovakvi vremenski uslovi doprinose bujnom porastu nadzemne mase biljaka i razvoju korenovog sistema u površinskom delu zemljišta, a takve biljke izrazito nepovoljno reaguju na nedostatak vode u drugom delu vegetacionog perioda (tabela 1).

Sumirajući podatke o padavinama i temperaturama može se konstatovati da je za rastenje i razviće soje bila najpovoljnija 2016. godina.

Rezultati i diskusija

Analizom dobijenih rezultata može se uočiti da je prosečan prinos zrna soje u ovom trogodišnjem istraživanju iznosio 2.315,1 kg ha^{-1}. Najveći prinos zrna soje ostvaren je u 2016. godini i to 3.820,2 kg ha^{-1}. Bio je veći za 2.750,9 kg ha^{-1} u odnosu na 2017. godinu i za 1.764,5 kg ha^{-1} u odnosu na 2015. godinu. Takođe, u 2015. godini ostvaren je značajno viši prinos nego u 2017. godini kao posledica veće količine padavina tokom avgusta meseca odnosno u fazi nalivanja zrna. Rezultati se slažu sa istraživanjima autora (Doss i Thulow, 1974; Brown et al., 1985; Griffin et al., 1985) koji ističu da je faza nalivanja semena soje najkritičnija i da nedostatak vode u ovom periodu ima najveći uticaj na produktivnost soje.

Nedostatak vode ima veći uticaj na visinu prinosa od genotipa, što je u saglasnosti sa rezultatima Đukić et al. (2009) i Vidić et al. (2009). Kod sorte Rubin dobijen je najveći prinos zrna koji je bio za 5,69% veći u odnosu na sortu Sava i 7,29% u odnosu na sortu Galina. Razlike su statistički značajne. Posmatrano po godinama, sorta Rubin je u sve tri godine ostvarila najviši prinos. Ovo povećanje se kretalo u intervalu od 2,03% do 18,94% u odnosu na sortu Sava i 5,34–8,47% u odnosu na sortu Galina.

Prosečni prinos soje se povećao sa povećanjem broja prohoda međurednim kultivatorom u toku vegetacionog perioda soje. Najviši prinos soje ostvaren je u varijanti sa tri međuredne kultivacije. U odnosu na kontrolnu varijantu prinos je bio veći za 7,33%. Sa jednom međurednom kultivacijom povećanje prinosa je iznosilo 5,33%, a sa dve međuredne kultivacije 7,10% u odnosu na kontrolnu varijantu (bez kultivacije). Povećanje prinosa posledica je, između ostalog, smanjene evapotranspiracije zemljišne vlage i sprečavanja poniranja vode u dublje slojeve. Ovo omogućava bolje čuvanje vode u zemljištu u kritičnim periodima za vodu tokom letnjih meseci, a takođe i povećava aktivnost mikroorganizama kao i intenzivniju mineralizaciju organske materije, što u krajnoj meri utiče na povećanje prinosa. Osnova povećanja prinosa je u simbiozi između korena i mikroorganizama. Bolja aeracija zemljišta doprinosi povećanju broja formiranih kvržica na korenu soje odnosno povećanju količine azota koji biljci stoji na raspolaganju.

Tabela 2. Uticaj međuredne kultivacije na prinos soje (kg ha^{-1}) u periodu od 2015. do 2017. godine.
Table 2. The influence of inter-row cultivation on the yield of soybean (kg ha-1) in the period from 2015 to 2017.

Godina (A)/ *Year (A)*	Sorta (B)/ *Cultivar (B)*	Međuredna kultivacija/ *Inter-row cultivation (C)* 0	1	2	3	Prosek (AxB)/ *Average (AxB)*	Prosek/ *Average (A)*
2015	Galina	1.797,0	1.934,0	1.970,0	1.989,0	1.922,5	2.055,7
	Sava	1.957,0	2.108,0	2.165,0	2.172,0	2.100,5	
	Rubin	2.010,0	2.148,0	2.202,0	2.216,0	2.144,0	
	Prosek (A×C)	1.921,3	2.063,3	2.112,3	2.125,7		
2016	Galina	3.588,0	3.742,0	3.789,0	3.796,0	3..728,8	3.820,2
	Sava	3.750,0	3.793,0	3.817,0	3.810,0	3.792,5	
	Rubin	3.787,0	3.945,0	4.010,0	4.015,0	3.939,3	
	Prosek (A×C)	3.708,3	3.826,7	3.872,0	3.873,7		
2017	Galina	968,0	1.088,0	1.133,0	1.126,0	1.078,8	1.069,3
	Sava	868,0	966,0	989,0	990,0	953,3	
	Rubin	1.062,0	1.178,0	1.225,0	1.239,0	1.176,0	
	Prosek (A×C)	966,0	1.077,3	1.115,7	1.118,3	Prosek (B)	
Prosek (BxC)/ *Average (BxC)*	Galina	2.117,7	2.254,7	2.297,3	2.303,7	2.243,3	
	Sava	2.191,7	2.289,0	2.323,7	2.324,0	2.282,1	
	Rubin	2.286,3	2.423,7	2.479,0	2.490,0	2.419,8	
	Prosek (C)	2.198,6	2.322,5	2.366,7	2.372,6		
	Ukupni prosek 2015–2017 *Total average (2015–2017)*					2.315,1	

LSD	Faktori ispitivanja/*Testing factors* A	B	C	AxB	AxC	BxC	AxBxC
1%	65,34	48,27	32,7	83,06	71,52	66,38	115,4
5%	43,13	35,23	24,66	61,17	52,81	49,97	87,01

Takođe, ovo dovodi do povećanja aktivnosti korena gajenih biljaka, a pogoduje i razvoju aerobnih mikroorganizama. Većina ovih mikroorganizama ima sposobnost „izvlačenja" fosfora i kalijuma iz kristalne rešetke minerala u zemljištu i prebacivanja u zemljišni rastvor, što ih čini dostupnim za biljke. U krajnjoj instanci, bolja provetrenost zemljišta, usled međuredne kultivacije, pogoduje i boljoj biološkoj fiksaciji azota. Biološkom fiksacijom obezbeđuje se od 25% do 75% potreba biljaka za ovim elementom (Zapata et al., 1987). Kvržične bakterije u simbiozi sa biljkom domaćinom stvaraju aktivne nodule – kvržice (biološke fabrike azota) na njenom korenu i na taj način fiksiraju do 180 kg ha^{-1} N godišnje iz vazduha (Milošević i Jarak, 2005). U oraničnom sloju zemljišta, gde je povoljna aeracija i vlaga, formira se veći broj kvržica, dok ih u sloju ispod 30 cm skoro i nema (Graham, 2000). Smanjena biološka fiksacija azota rezultat je akumulacije ureida u kvržicama (Vadez et al., 2000). Akumulacija je rezultat novosintetisanih ureida, ali i postojećih koji usled nedostatka vode nisu mogli da se transportuju (Collier i Tegeder, 2012). Akumulirani ureidi u nodulama zbog kašnjenja u transportu oštećuju biološku fiksaciju azota (Collier i Tegeder, 2012), jer su toksični za azotofiksirajuće bakterije odnosno njihov enzimski aparat (Vadez et al., 2000). Veća koncentracija ureida dovodi do inhibicije nitrogenaze i na taj način otežava snabdevanje biljaka azotom (Ladrera et al., 2007). Nedostatak vode predstavlja jedan od najznačajnijih faktora koji utiče na aktivnost azotofikcirajućih bakterija (Hungria i Vargas, 2000). Međurednom kultivacijom smanjuje se evaporacija i čuva se zemljišna vlaga, što utiče na povećanu aktivnost mikroorganizama odnosno na fiksaciju atmosferskog azota, a što se u krajnjoj liniji odnosi na povećanje prinosa.

U godinama sa deficitom padavina konstatovan je veći efekat međuredne kultivacije. Povećanje prinosa zrna soje se u 2017. godini kretalo u intervalu od 10,33% do 13,62%, a u 2016. godini od 3,09% do 4,27% u odnosu na kontrolnu varijantu (bez kultivacije). Sorte soje su različito reagovale na međurednu kultivaciju. Najveće povećanje prinosa zrna ostvareno je kod sorte Galina na varijantama sa jednom i dve međuredne kultivacije i to 6,08% i 7,82%. Kod ove sorte nije uočena statistički značajna razlika u prinosu zrna između varijanti sa dve i tri međuredne kultivacije. Najveći uticaj na povećanje prinosa primenom tri međuredne kultivacije ostvaren je kod sorte Rubin. Prinos je povećan za 8,18%. Kod sorte Sava konstatovan je najslabiji uticaj različitih varijanti međuredne kultivacije na povećanje prinosa zrna. Prinos je povećan od 4,25% do 5,69%.

Zaključak

Nedostatak vode u fazi nalivanja semena je najviše uticao na prinos zrna soje. Prinos zrna soje više je zavisio od sorte, a manje od agroekoloških uslova odnosno deficita padavina. U godinama sa manjom količinom padavina, efekat međuredne kultivacije na prinos zrna soje bio je veći. Prinos zrna soje se povećavao sa povećanjem broja međurednih kultiviranja. Sa jednom međurednom kultivacijom povećanje prinosa je iznosilo 5,33%, sa dve međuredne kultivacije 7,10%, a sa tri 7,33%. Uticaj međuredne kultivacije na povećanje prinosa je zavisio i od sorte. Najveći prinos zrna soje, u proseku za sve varijante međuredne kultivacije, konstatovan je kod sorte Rubin.

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INTER-ROW CULTIVATION – AN AGRO-TECHNICAL MEASURE FOR INCREASING SOYBEAN YIELD

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A b s t r a c t

In order to examine the influence of inter-row cultivation on the soybean yield, a trial was set up in the Agricultural School in Backa Topola from 2015 to 2017. Three soybean varieties were selected at the Institute of Field and Vegetable Crops in Novi Sad. Galina, Sava and Rubin were used. The trials included the different number of inter-row cultivations: control – without inter-row cultivation, one inter-row cultivation, two and three inter-row cultivations of soybean crops. Obtained results showed that an average yield of soybean increased with an increase in the number of inter-row cultivations during the soybean vegetation period. With one inter-row cultivation, the yield increase was 5.33%, with two inter-row cultivations – 7.10% and with three cultivations – 7.33%. In the years with a lower precipitation, the influence of intra-row cultivation was much more effective. In 2017, the increase ranged from 10.33% to 13.62%, and in 2016 from 3.09% to 4.27%. Yield was increased due to reduced evapotranspiration of soil moisture as well as prevention of descending of water into deeper layers. During summer, this allowed better water conservation in the soil for critical periods, and also increased the activity of microorganisms as well as more intensive mineralization of organic matter, which ultimately influenced the yield.

Key words: soybean, yield, inter-row cultivation, variety.

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GENETIC STUDIES OF FIBRE YIELD-RELATED TRAITS AND DAYS TO ANTHESIS IN SOME KENAF (*Hibiscus cannabinus L.)* ACCESSIONS

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Abstract: Kenaf (*Hibiscus cannabinus L.)* is an economically important and multi-purpose natural fibre crop with several industrial applications. However, its potentials have not been fully maximised due to poor yield and its narrow genetic base which limited the available hybrids. The low yield is attributed to high photoperiod sensitivity of most kenaf accessions because it reduces the vegetative growth. This study attempts to understand the genetic architecture of days to anthesis of kenaf towards the development of a photo-insensitive kenaf hybrid. Two early maturing Nigerian kenaf accessions: NHC (12)1 and NHC (3)2, and two late maturing accessions (NHC [9]2 and NHC 15) were crossed to generate F_1 population. The F_1 hybrid together with its parents and its reciprocals were planted in a randomised complete block experiment design with three replicates. Data were collected on days to anthesis (DTA), plant height (HAH), basal stem girth (GAH), base diameter (BDAH) and weight at harvest (WAH) for analysis. The mean squares were significant for DTA, HAH, DBAH, GAH and WAH. DTA exhibited the highest broad-sense heritability value (0.98) among other traits. The GCA: SCA ratio for DTA and BDAH signifies that the effect of non-additive genes was prevalent because it was lower than a unity while the additive gene action was predominant in HAH. The negative GCA estimates for NHC (12)1 and NHC (9)2 indicated a poor combining ability. Only NHC (3)2 x NHC (9)2 showed good specific combining ability (-5.75, 0.33, 0.85, 91.46) for DTA, GAH, BDAH and WAH respectively. NHC (12)1 x NHC (9)2, NHC (3)2 x NHC (9)2, NHC (3)2 x NHC 15, NHC (9)2 x 3NHC (3)2, NHC (9)2 x NHC 15, NHC 15 x NHC (3)2, NHC 15 x NHC (9)2 showed negative significant percent of F_1 heterosis above the mid-parent in days to anthesis and could be employed to breed photo-insensitive early maturing kenaf.

Key words: fibre yield, heterosis, photo-insensitive kenaf, combining ability, hybrids.

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Introduction

Kenaf (*Hibiscus cannabinus L.*) is one of the most important natural fibre crops. Its cultivation and improvement have been neglected due to its restricted old folkloric utilisations; for twine, rope, gunny-bag and sackcloth production. However, it is currently attracting tremendous attention due to its new application and future potentials. It has the potential to be used as an alternative raw material to replace wood fibre in pulp and paper industry. For instance, it has been reported that kenaf produces fibre approximately three to five times as Southern pine (Rymsza, 1999; Lemahieu et al., 2003). Kenaf biomass has been successfully investigated as an alternative renewable source and sustainable feedstock for the production of biofuel (Saba et al., 2015). Recently, kenaf fibres have become more attractive to the automotive industry, to enhance desired mechanical properties as automotive structural components (Hassan et al., 2017). It is also used in oil spill clean-ups and removal of heavy metals from aqueous solution (Yusof et al., 2015). The sorbent materials produced from kenaf fibres have shown a superior adsorption efficiency for heavy metal removal from water bodies as compared to activated carbon (Shamsudin et al., 2016). The stem core and fibre of different varieties of kenaf grown in Nigeria have been revealed to be effective absorbents (Balogun and Raji, 2016). Despite the potential application of kenaf, few hybrids are available, especially in developing countries where its production can serve as a reliable source of a sustainable livelihood.

Most local varieties are highly photosensitive, which leads to early flowering. This consequently terminates the vegetative growth (Webber and Bledsoe, 2002) and results in low fibre yields. The knowledge of a day-length effect on kenaf growth and biomass yield is fundamental for the selection of the best cultivar for the production (Webber et al., 2002). Therefore, it is important to develop hybrids that would continue to grow irrespective of flowering at a critical daylight period for maximum fibre yield. To improve kenaf fibre production, identification of superior parents as well as the promising cross combinations is paramount for its improvement. Information on phenotypic and genotypic variances as well as heritability estimates for fibre yield and other related characters are essential for designing a successful breeding program. The general combining ability (GCA) is directly related to the breeding value of parents and associated with the additive genetic effects. On the other hand, the specific combining ability (SCA) is the relative performance of a cross that is associated with non-additive gene action, predominantly contributed by dominance, epistasis, or genotype × environment interaction effects. Heritability is the measure of the proportion of the genetic variance out of the total phenotypic variance present in a population. It could either be broad-sense or narrow-sense heritability and it indicates the degree to which off-spring can be expected to resemble their parents for a specific trait. The knowledge on the magnitude of genetic variability and heritability estimates for fibre yields is penitent for kenaf improvement. This study evaluates the additive and dominance effects of genes involved in days to anthesis in kenaf as well as heterosis for days to anthesis and fibre yield-related traits. Our results provide important insights into the identification and selection of superior genotypes that are less sensitive to photoperiodism and indeterminate flowering.

Materials and Methods

Four accessions based on the state of origin and flowering habits (Table 1) were obtained from Gene Bank at the Department of Crop Protection and Environmental Biology, University of Ibadan, Nigeria. According to the formula designed by Griffing (1956) method 1, 16 crosses were made from the four parents (Ps), where the number of crosses = P (P-1). The total entries were therefore 16 (parents, crosses and reciprocals).

The mature F_1 (hybrids) seeds obtained from all possible crosses of the parents (two early maturing and two late maturing) and the parents were planted in a randomised complete block design with three replicates. Data were taken on numbers of days to flowering, plant height at harvest, basal girth at harvest, basal diameter at harvest and weight at harvest.

Table 1. Kenaf accession names based on the state of collection.

Accession name	Flowering habit	State of collection
NHC 12(1)	Early flowering	Plateau
NHC 9(1)	Late flowering	Adamawa
NHC 3(2)	Early flowering	Niger
NHC 15 (Improved variety)	Late flowering	

NHC = Nigeria *Hibiscus cannabinus.*

Statistical analysis

Genetic parameters were evaluated by analysis of variance and means were separated by the least significant difference (LSD < 0.05 and LSD < 0.01). Analysis of the combining ability of the parents and the hybrid plants was done following Griffing's Method 1 (Grifting 1956), where parents, F_1s and reciprocals were included. The magnitude of heterosis (MP: mid-parent) and heterobeltiosis (BP: better parent) were calculated using the formula of Pace et al. (1998):

BP= $\frac{(F1-P0)}{P0} x 100$ and MP = $\frac{(F1-P1)}{P1} x 100$, where F_1 is the value of a cross; P_0 is the mean value of both parental populations; and P_1 is the value of the better parental population.

Results and Discussion

The mean squares for various traits (DTA, HAH, DBAH, GAH and WAH) studied in association with days to flowering of parents and their F_1 hybrids (Table 2) revealed highly significant variations for all characters. It shows that there were significant differences between genotypes for these characteristics. The reciprocals were significant in days to anthesis ($p<0.05$) and HAH ($p<0.01$). This indicates a wide genetic variability for studied characters, which can facilitate genetic improvement using such kenaf accessions. The significant GCA and SCA for DTA, HAH, GAH indicate that the characters measured were controlled by both additive and non-additive gene actions. The current finding concurred with the earlier reports of Su et al. (2004). Genetic variability has been reported in the evaluation studies of kenaf agronomical traits (Siepe et al., 1997; Ogunbodede and Ajibade, 2001). Likewise, Balogun et al. (2007) reported variations in the photo and thermal sensitivities among local, improved and exotic kenaf accessions in Nigeria. The GCA: SCA ratio for DTA and BDAH indicates that effect of non-additive genes was prevalent because it was less than a unity while additive gene action was predominant in HAH. The significant difference observed in the reciprocal crosses for DTA and HAH suggested a high degree of recombinants that can be explored to identify which accession is the best for male or female parent. Furthermore, a cytoplasmic effect could influence the genetic control due to the significant reciprocal in days to anthesis and HAH which is similar to the result reported in flax (Mohammadi et al., 2010).

Table 2. Mean squares from analysis of variance, general combining ability (GCA), specific combining ability (SCA) and broad-sense heritability (H^2b) for days to anthesis and fibre yield-related traits.

Source	Df	DTA	HAH	BDAH	GAH	WWAH
Treatment	15.00	1466.82*	3142.11*	0.46*	3.47*	38059.082*
REP	2.00	6.57	1006.24	0.10	1.95	6128.34
GCA	2.00	777.90*	1712.68*	0.14	2*	6604.09
SCA	6.00	1689.51*	1218.10*	0.24	1.5*	23184.54*
Reciprocal	6.00	118.30*	829.43**		0.73	6330.00
ERROR	30.00	18.64	317.89		0.56	WWAH
H^2b		0.98	0.66		0.52	38059.082*
GCA/SCA		0.46	1.41		GAH	6128.34

* – significant at 0.05, ** – significant at 0.01, REP = Replicate, DTA = Days to anthesis, HAH = Height at harvest, GAH = Girth at harvest, WAH = Weight at harvest, BDAH = Base diameter at harvest.

A high broad-sense heritability observed in DTA (0.98), HAH and WAH (0.66) was due to larger additive and dominance variances than the environmental variance. This suggests the possibility of genetic improvement of these traits since the selection of superior individual plants is possible in segregating generations. Bhamre et al. (1991) reported that the day from emergence to 50% flowering was determined mainly by additive genetic effects, while Xu et al. (1994) found predominantly additive effects in the evaluation of the number of days from seedling emergence to first flowering in diallelic crosses between cultivated kenaf and its wild sources.

In Table 3, days to anthesis ranged from 53 to 127 days with an average mean of 67 days. The average means for HAH, GAH, BDAH, WAH were 225.84cm, 7.40cm, 2.25cm, 338.98g respectively. At harvesting, NHC (9)2 x NHC (12)1 had the maximum values in height, girth, base diameter and wet weight. NHC15 had the minimum values in height, girth, and base diameter. NHC (3)2 had the minimum wet weight. The higher mean values (89.50, 280cm, 8.91cm, 2.82cm, 542.50g) observed in NHC (9)2xNHC (12)1 for DTA, HAH, GAH, BBAH, WAH respectively indicated better performance over the other crosses in all the traits.

Table 3. Mean values of parents and F_1 hybrids for five characters in some selected Nigerian kenaf crosses.

CROSSES	DTA	HAH (cm)	GAH (cm)	BDAH (cm)	WAH (g)
NHC (12)1	54.93	191.47	7.36	2.07	237.08
NHC (3)2	110.20	191.13	6.11	1.67	151.33
NHC(9)2	55.53	212.47	6.08	1.74	167.50
NHC 15	127.25	163.40	5.14	1.55	220.00
NHC(12)1 X NHC(3)2	55.60	245.73	7.58	2.30	443.33
NHC(12)1 x NHC(9)2	53.47	239.80	7.69	2.35	343.33
NHC(12)1 x NHC 15	56.92	252.91	8.38	2.59	399.44
NHC(3)2x NHC(12)1	56.40	229.95	8.23	2.51	408.89
NHC(3)2x NHC(9)2	55.64	262.93	8.10	2.62	428.33
NHC(3)2x NHC 15	60.80	193.33	7.08	2.25	312.50
NHC(9)2x NHC(12)1	89.50	280.00	8.91	2.82	542.50
NHC(9)2x3 NHC(3)2	65.07	234.56	8.67	2.64	433.33
NHC(9)2x NHC 15	54.50	267.60	8.58	2.68	340.56
NHC 15x NHC(12)1	56.03	210.73	6.97	2.08	320.83
NHC 15x NHC(3)2	64.87	232.75	7.07	2.24	443.06
NHC 15x NHC(9)2	58.30	204.75	6.44	1.87	231.67
Minimum	53.47	163.40	5.14	1.55	151.33
Maximum	127.25	280.00	8.91	2.82	542.50
Mean	67.19	225.84	7.40	2.25	338.98
LSD	12.47	51.50	1.57	0.75	178.50

LSD = Least significant difference, DTA = Days to anthesis, HAH = Height at harvest, GAH = Girth at harvest, WAH = Weight at harvest and BDAH = Base diameter at harvest.

Accessions NHC (12)1 and NHC (9)2 showed negative GCA effects for days to anthesis, whereas accessions NHC (9)2 and NHC 15 showed positive GCA effects for the same (Table 4). GCA for NHC (3)2 and NHC 15 was negative for HAH, GAH, BDAH, and WAH, but it was significantly positive for DTA. NHC

(12)1 showed good combining ability for GAH and WAH while NHC (9)2 exhibited good combining ability for HAH with significantly negative DTA. The negative GCA estimates for NHC (12)1 and NHC (9)2 indicated poor ability to transfer its genetic superiority to hybrids. The negative DTA GCA estimates and significantly positive GCA estimates for other traits are important for selection in breeding photo-insensitive kenaf. Significant GCA demonstrates that an evaluation of parental phenotypes would be sufficient for determining their breeding potentials since the GCA effects of parents are the measure of their ‘breeding value’ as an average of their performance in hybrids. The existence of this significant GCA effect implies the possibility of using such parent as a source for earliness and higher yield components because the suitable traits are easily transmitted to its progenies.

Table 4. Estimates of general combining ability on five characters in some selected Nigerian kenaf accessions.

PARENTS	DTA	HAH	BDAH	GAH	WAH
NHC (12)1	-7.47*	4.41	0.10	0.41*	27.58*
NHC (3)2	5.16*	-3.15	-0.01	-0.03	7.53
NHC (9)2	-6.25*	13.48*	0.06	0.17	-7.14
NHC 15	8.55*	-14.74*	-0.15*	-0.55*	-27.97*
SE	1.32	5.46	0.08	0.23	18.92

* – significant at 0.05, NHC = Nigeria *Hibiscus cannabinus*, DTA = Days to anthesis, HAH = Height at harvest, GAH = Girth at harvest, WAH = Weight at harvest and BDAH = Base diameter at harvest, SE = Standard error.

Table 5 shows the SCA estimates of each inbred line in a series of crosses. Six crosses NHC (12)1 x NHC (3)2, NHC (12)1 x NHC 15, NHC (3)2 xNHC (9)2, NHC (3)2 x NHC 15, NHC (9)2 x NHC 15 and NHC (12)1 x NHC (9)2 had significant negative SCA effects for days to anthesis. However, among all the crosses only NHC (3)2 x NHC (9)2 had a significant positive SCA effects for base diameter, girth and wet weight at harvest. However, SCA was significantly negative for days to anthesis in the reciprocal crosses. The cross NHC (12)1 x NHC (9)2 was significantly positive for DTA and WAH, with the highest value in HAH while its reciprocal cross NHC (12)1 x NHC (9)2 was significantly negative for all traits. Reciprocal cross NHC (9)2 x NHC 15 showed significant negative SCA effects on days to anthesis but was significantly positive for plant height, girth and base diameter at harvest. The significant SCA effects suggest a deviation of a specific cross from the mean performance of the inbred parents. Generally, high SCA effects from parents with combining abilities (i.e. good GCA × good GCA) are attributed to additive × additive gene action. When high SCA effects cross resulted from good × poor general combiner parents, additive effects of the good general combiner parent and epistatic effects of the poor general combiner are usually involved. Similarly, complementary gene action, as well as dominance ×

dominance type of non-allelic gene interaction producing overdominance could lead to high SCA effects between low × low crosses. Hybrids having significant positive SCA are due to favourable combinations of dominance effects when those parents are crossed. Only NHC (12)1 x NHC (9)2 cross resulted in significant positive SCA while its reciprocal cross had negative SCA for DTA. This result implies that a maternal effect in the inheritance for the cross should be taken into consideration because selection for the better accession as a female parent would be valuable to breed a photo-insensitive hybrid. Gray et al. (2006) demonstrated that some dominance effects also occurred in the form of a partial dominance for early flowering in kenaf. Among all the crosses made, only NHC (3)2 x NHC (9)2 showed good specific combining ability (-5.75, 0.33, 0.85, 91.46) for DTA, GAH, BDAH and WAH respectively. Hybrids having significant positive SCA are due to favourable combinations of dominance effects when those parents are crossed. The specific combinations with negative SCA effects for DTA and positive SCA effects for other traits can be explored in improvement of early maturity of photo-insensitive kenaf.

Table 5. Estimates of the specific combining ability effect and the reciprocal effect on five traits in some selected kenaf accessions.

SPECIFIC COMBINING EFFECTS	DTA	HAH	BDAH	GAH	WAH
NHC (12)1xNHC (3)2	-8.88*	10.74	0.07	0.13	52.02
NHC (12)1xNHC (9)2	18.01*	16.17	0.18	0.32	83.49*
NHC (12)1 x NHC 15	-11.80*	16.30	0.13	0.41	21.55
NHC (3)2xNHC (9)2	-5.75*	12.58	0.33*	0.85*	91.46*
NHC (3)2x NHC 15	-18.07*	5.09	0.16	0.26	59.24
NHC (9)2x NHC 15	-13.09*	11.59	0.11	0.49	-17.76
Standard error	2.41	9.97	0.14	0.42	34.55
RECIPROCAL EFFECTS					
NHC(12)1xNHC (3)2	-0.40	7.89	-0.11	-0.32	17.22
NHC(12)1xNHC (9)2	-18.02*	-20.10*	-0.23	-0.61	-99.58*
NHC (12) x NHC15	0.44	21.09*	0.26	0.71	39.31
NHC (3)2xNHC (9)2	-4.71	14.19	-0.01	-0.28	-2.50
NHC (3)2x NHC 15	-2.03	-19.71	0.01	0.01	-65.28
NHC (9)2x NHC 15	-1.90	31.43*	0.41*	1.07*	54.44
Standard error	3.05	12.61	0.18	0.53	43.70

* – significant at 0.05, NHC = Nigeria *Hibiscus cannabinus*, DTA = Days to anthesis, HAH = Height at harvest, GAH = Girth at harvest, WAH = Wet weight at harvest and BDAH = Base diameter at harvest.

Mid-parent and better parent heterosis for five characters in some selected Nigerian kenaf accessions

Percentage heterosis relative to mid-parents (MPs) was negatively significant for eight out of the fourteen crosses in days to anthesis (-48.79 to -3.20), whereas the mid-parents were significantly positive in all crosses for height (8.95–42.54), and girth (11.52–42.23). However, eight crosses in base diameter (34.45 to 62.65) and ten crosses in weight at harvest (19.57–171.82) were significantly positive mid-parents (Table 6). The lowest significantly negative DTA value (-48.79; MP and -44.83; HP) was recorded for cross NHC (3)2 x NHC15. The evaluation of heterosis in half diallel crosses: NHC (12)1 x NHC (9)2, NHC (3)2 x NHC (9)2, NHC (3)2 x NHC 15, NHC (9)2 x 3NHC (3)2, NHC (9)2 x NHC 15, NHC 15 xNHC (3)2, NHC 15 x NHC (9)2 showed a negative significant effect on percentage of F_1 heterosis above mid-parent's days to flowering. They could be employed to breed photo-insensitive early maturing kenaf accessions while NHC (9)2 x NHC (12)1 with positive heterosis would do well where late maturing kenaf accessions perform well.

Table 6. Mid-parent heterosis (%) for five characters in some selected Nigerian kenaf crosses.

CROSSES	DTA	HAH	GAH	BDAH
NHC(12)1xNHC(3)2	-32.66	28.45*	12.57*	23.04
NHC(12)1xNHC(9)2	-3.20*	18.73*	14.38*	23.57
NHC(12)1xNHC 15	-37.52	42.54*	34.12*	43.08*
NHC(3)2xNHC(12)1	-31.69	20.20*	22.20*	34.45*
NHC(3)2x NHC(9)2	-32.85*	30.29*	32.93*	53.59*
NHC(3)2x NHC 15	-48.79*	9.06*	25.96*	40.07*
NHC(9)2xNHC(12)1	62.04*	38.64*	32.59*	47.82*
NHC(9)2x3NHC(3)2	-21.48*	16.23*	42.23*	54.71*
NHC(9)2x NHC 15	-40.37*	42.39*	52.94*	62.65*
NHC 15xNHC(12)1	-38.49	18.77*	11.52*	14.82
NHC 15x NHC(3)2	-45.36*	31.30*	25.67*	38.98*
NHC 15x NHC(9)2	-36.21*	8.95*	14.82*	13.42
minimum	-48.79	8.95	11.52	13.42
maximum	62.04	42.54	52.94	62.65
CD	3.22	7.03	1.44	0.85

CD = Critical difference, DTA = Days to anthesis, HAH = Height at harvest, GAH = Girth at harvest, WAH = Wet weight at harvest and BDAH = Base diameter at harvest.

Heterosis percentages relative to better parents (BPs) were negatively significant for three out of fourteen crosses for days to anthesis (range of -44.83 to -2.67) but positively significant for all crosses for base diameter (0.45 to 53.56) as shown in Table 7. At maturity, eleven crosses had significant percentage heterosis for plant height (1.15 to 32.09), nine crosses for base girth (2.99 to 41.92) and ten crosses for wet weight (5.30 to 128.82). Meanwhile, crosses NHC (12)1 x NHC (9)2, NHC (3)2 x NHC 15, NHC 15 x NHC (3)2 were negatively significant in terms of percentage F_1 heterosis above high-parent in days to flowering in addition to other traits, but NHC (9)2 x NHC (12)1 and NHC (9)2 x 3NHC (3)2 crosses had significant positive days to anthesis and other traits. Higher heterosis value over the better parent and the mid-parent suggested the absence of epistasis and prevalence of partial or complete dominance of genes for yield and days to flowering. The percent F_1 heterosis above the high-parent could be explored to identify crosses that would lead to superior photo-insensitive transgressive segregants. However, further research on F_2 and backcross populations and correlation coefficient among crosses is important to know the extent and nature of the relationship between these contributing characters and final yield.

Table 7. High-parent heterosis (%) for five characters in some selected Nigerian kenaf crosses.

CROSSES	DTA	HAH	GAH	BDAH	WAH
NHC(12)1xNHC(3)2	1.21	28.34*	2.99*	11.16*	86.99*
NHC(12)1xNHC(9)2	-2.67*	2.86*	4.44*	13.94*	44.82*
NHC(12)1xNHC 15	3.61	32.09*	13.89*	25.18*	68.48*
NHC(3)2xNHC(12)1	2.67	20.10*	11.80*	21.47*	72.47*
NHC(3)2x NHC(9)2	0.20*	23.75*	3.22*	50.22*	155.72
NHC(3)2x NHC 15	-44.83*	1.15*	15.99	35.10*	42.05*
NHC(9)2xNHC(12)1	62.92*	31.79*	21.06*	36.30*	128.82*
NHC(9)2x3NHC(3)2	17.17*	10.40*	1.92*	51.31*	158.71
NHC(9)2x NHC 15	-1.86	25.95*	41.12*	53.56*	54.80*
NHC 15xNHC(12)1	2.00	10.06*	-5.30*	0.45*	35.33*
NHC 15x NHC(3)2	-41.14*	21.77*	15.72	34.05*	101.39*
NHC 15x NHC(9)2	4.98	-3.63	5.95*	7.08*	5.30*
min	-44.83	-3.63	-5.3	0.45	5.30
max	62.92	32.09	41.92	53.56	158.71
CD	3.22	6.54	1.34	0.79	12.18

CD = Critical difference, DTA = Days to anthesis, HAH = Height at harvest, GAH = Girth at harvest, WAH = Wet weight at harvest and BDAH = Base diameter at harvest.

Conclusion

Most of the crosses showed the presence of sufficient hybrid vigour in days to flowering as well as other yield parameters. NHC (12)1 x NHC (9)2, NHC (3)2 x NHC (9)2, NHC (3)2 x NHC 15, NHC (9)2 x 3NHC (3)2, NHC (9)2 x NHC 15, NHC 15 x NHC (3)2, NHC 15 x NHC (9)2 showed significant negative percentage F_1 heterosis in days to anthesis and could be utilised in the breeding of photo-insensitive early maturing kenaf accessions.

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GENETIČKA ISTRAŽIVANJA KOMPONENTI PRINOSA VLAKNA I BROJA DANA DO PUNOG CVETANJA KOD NEKIH PRINOVA KENAFA (*Hibiscus* cannabinus *L.)*

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R e z i m e

Kenaf (*Hibiscus cannabinus L.*) je ekonomski važna prirodna kultura za proizvodnju vlakna sa višenamenskom industrijskom primenom. Međutim, njegovi potencijali nisu u potpunosti iskorišćeni zbog niskog prinosa i njegove uske genetičke baze, koja je ograničila raspoložive hibride. Nizak prinos se pripisuje visokoj fotoperiodskoj osetljivosti kod većine genotipova kenafa, što utiče na smanjenje vegetativnog porasta. Ovim istraživanjem pokušava se shvatiti genetička arhitektura broja dana do punog cvetanja kenafa kako bi se razvio fotoneosetljiv hibrid kenafa. Dva ranostasna nigerijska genotipa kenafa: NHC (12)1 i NHC (3)2, i dva kasnostasna genotipa (NHC [9]2 i NHC 15) ukršteni su da bi se proizvela F_1 populacija. F_1 hibridi zajedno sa svojim roditeljima i recipročnim kombinacijama, posađeni su u eksperimentu po potpuno slučajnom blok sistemu sa tri ponavljanja. Za analizu su sakupljeni podaci o broju dana do punog cvetanja (engl. *days to anthesis* – DTA), visini biljke (engl. *plant height* – HAH), obimu stabljike (engl. *basal stem girth* – GAH), prečniku osnove (engl. *base diameter* – BDAH) i težini pri berbi (engl. weight at harvest – WAH). Sredine kvadrata su bile značajne za DTA, HAH, DBAH, GAH i WAH. U poređenju sa drugim osobinama najveća vrednost koeficijenta heritabilnosti u širem smislu (0,98) utvrđena je za DTA. Odnos GCA:SCA za osobine DTA i BDAH ukazuje da je efekat neaditivnih gena preovladao, dok je aditivno delovanje gena bilo preovlađujuće kod HAH. Negativne procene GCA za NHC (12) 1 i NHC (9) 2 ukazale su na njihovu lošu kombinacionu sposobnost. Dobru specifičnu kombinacionu sposobnost (-5,75, 0,33, 0,85, 91,46) za DTA, GAH, BDAH odnosno WAH pokazala je samo kombinacija ukrštanja NHC (3)2 x NHC (9)2. U kombinacijama ukrštanja NHC (12)1 x NHC (9)2, NHC (3)2 x NHC (9)2, NHC (3)2 x NHC 15, NHC (9)2 x 3NHC (3)2, NHC (9)2 x NHC 15, NHC 15 x NHC (3)2, NHC 15 x NHC (9)2 kod F_1 hibrida utvrđen je značajan, negativan procenat heterozisa u odnosu na srednju vrednost roditelja za broj dana do punog cvetanja i kao takve ove kombinacije bi se mogle iskoristiti za stvaranje ranostasnog fotoneosetljivog kenafa.

Ključne reči: prinos vlakna, heterozis, fotoneosetljiv kenaf, kombinaciona sposobnost, hibridi.

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INFLUENCE OF RHIZOME MASS ON THE CROP ESTABLISHMENT AND DRY MATTER YIELD OF *Miscanthus×giganteus* OVER TEN SEASONS

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Abstract: The aim of the present investigation was to assess the influence of rhizome mass on the success of plantation establishment and biomass yield of the bioenergy crop *M.* × *giganteus* during 10 years of cultivation. The experiment included three treatments with different rhizome masses: 10–20 g (very low); 25–35 g (low), and 40–60 g (medium mass). Planting density was 2 rhizomes m^{-2}. The plants were harvested by mowing of the whole above-ground biomass each year in February. Out of the total number of planted rhizomes, the lowest emergence was noticed in very low mass rhizomes. In the first season, the greatest number of stems and crop height were encountered under the treatment with the highest rhizome mass. In the second season, crop heights were almost equal in all treatments. During the first two seasons, the highest biomass yields were recorded under the treatments with the highest rhizome masses. Although the analyzed parameters were highest with the rhizomes of 40–60g during the crop establishing stage, starting from the third season of cultivation, high yields of above-ground biomass may be obtained also with lower mass rhizomes. Having the highest biomass yield (25.85±7.36 Mg DM ha^{-1}), the crop established with rhizomes of 25–35 g clearly stood out.

Key words: biomass yield, crop establishment, *M.*× *giganteus*, rhizome mass.

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Introduction

Miscanthus × giganteus Greef et Deu. is a perennial biomass crop particularly suitable for substitution of fossil fuels in energy production. It is a non-invasive perennial grass crop, which is a naturally sterile allotriploid, 2n = 3x = 57 (Nishiwaki et al., 2011), originating from East Asia. Regarding biomass production, it may be cultivated continuously for 15–20 seasons. *M.× giganteus* is a C_4 grass with highly efficient utilization of light and water (Lewandowski et al., 2000; Cosentino et al., 2007). The biofuel potential of miscanthus is highly valued (Perić et al., 2018a, b). Thanks to efficient biomass production, which has very good combustion quality (Cvetković et al., 2016; Bilandžija et al., 2017), miscanthus should give a significant contribution to sustainable agricultural production of combustible biomass in the near future (Dohleman et al., 2012; Mishra et al., 2013; Perić et al., 2018a). The high yield of miscanthus, together with its relatively low macronutrient concentrations and intermediate removal rates, indicates its advantages over other grasses as a biomass crop choice (Oliveira et al., 2017). Along with profitability, it is estimated that the energy production based on miscanthus cultivation will also contribute to the multi-functionality of agriculture (Daraban et al., 2015).

Contrary to the majority of other agricultural crops, miscanthus is a plant with an extensive root system, which remains dormant during winter, but it may respond quickly to increased plant requirement for assimilates at the start of growing season in the spring (Himken et al., 1997). Rhizome mass comprises approximately 2/3 of root biomass (Dželetović and Glamočlija, 2015). It has a shallow root system, with almost 90% of root biomass concentrated in the surface soil layer (0–35 cm) (Monti and Zatta, 2009). However, its roots reach the depth of 2 m, thus enabling absorption of soil moisture during dry summer months (Neukirchen et al., 1999). This depth surpasses rooting depths of most annual cultivated crops. Deeply rooted crops, like miscanthus, are more tolerant to drought, because they have access to more humid soil layers (Chaves et al., 2002).

Rhizomes have the key role in nutrient translocation in miscanthus. From the end of summer to winter, most nutrients are efficiently translocated from above-ground biomass to rhizomes, where they are stored until the next season, when they mobilize for the purpose of growth and development of new shoots (Masters et al., 2016; Nassi o Di Nasso et al., 2011). At the end of vegetation season, a part of nutrients is returned to soil through discarded leaves. Thanks to nutrient cycling, their concentrations in above-ground biomass are low during winter (Masters et al., 2016; Nassi o Di Nasso et al., 2011; Singh et al., 2015), which makes the biomass a very good raw material for combustion (Bilandžija et al., 2014; Singh et al., 2015).

M.× giganteus crop may be established by planting rhizomes or by micro-propagation of plants in April or May. Currently, most *M.×giganteus* crops are established by rhizome planting (Atkinson, 2009). Plants propagated from rhizomes develop shoots faster and display a lower number of above-ground parts (stems), but the stems are stronger and denser than above-ground parts of micro-propagated plants which develop their shoots slower (Lewandowski, 1998). Good miscanthus crop establishment by rhizome propagation depends on three components (Hocking et al., 2011): 1) vigor, potential energy of sprouting from rhizome fragments; 2) land management and cultivation systems that enable appropriate density of planting of unimpaired rhizome fragments; 3) soil conditions during and after the planting. All these components should be optimal in order to obtain the best possible initial sprouting, which should be accompanied by further good stimulative management (Hocking et al., 2011).

The influence of rhizome mass on biomass yield of miscanthus was investigated only in the initial stage of the crop development (the first two seasons of cultivation). It was found that the initial planting density did not influence the maximal yield value, but it exerted an influence on the rate of achieving the maximal biomasses (Miguez et al., 2008). According to Pyter et al. (2010), rhizomes of 50–60 g should possess sufficient metabolic supplies to enable their survival during storage as long as 4 months, from digging up the rhizomes until their planting on new plots or in new areas of cultivation. According to the results of Humentyk et al. (2013), the optimal density is 15,000 plants ha^{-1}, with the rhizomes of 30–60 g. As for the crop establishment, rhizome purchase represents absolutely the greatest expense (Jain et al., 2010). Because of this, the crop producers, as a rule, insist on purchasing rhizomes with the highest mass. The aim of our investigation is to assess the influence of the planted rhizome mass on the success of culture establishment and on the biomass yield during the first 10 seasons of cultivation.

Materials and Methods

The field experiment was carried out on the experimental plot of INEP (Institute for the Application of Nuclear Energy), Zemun, Serbia (44°51´ N, 20°22´E, 82 m a.s.l.; Figure 1), on non-carbonate chernozem (pH in water: 6.7; pH in 1M KCl: 5.5; total organic C: 1.71%; total N: 0.14%; available P_2O_5: 6.0 mg 100 g^{-1}; available K_2O: 17.8 mg 100 g^{-1}).

Serbian climate is mostly moderate continental. Average July (the hottest month of the year) temperature is ≥22°C, and average January (the coldest month of the year) temperature values vary mostly between 0 and -2°C (Dželetović et al., 2013). In Serbia, annual precipitation curve displays the two maxima: in the late spring and in the late autumn, while winters and summers are mostly dry periods.

Experimental treatments included 3 different rhizome masses: (1) rhizomes of very low mass: 10–20 g, which are not regularly used for planting; (2) rhizomes of low mass: 25–35 g; and (3) rhizomes of medium mass: 40–60 g, which are considered appropriate for planting. The experimental plots of 20 m^2 (5m×4m) each were positioned in three replications in a randomized complete block design. The rhizomes were planted on previously prepared soil surface, at 10 cm depth, on April 19, 2008. The planting was performed with the fragments of 3-year-old rhizomes, which had been stored for 30 days, between digging up and planting. This is the storage period most frequently encountered in Serbia: rhizomes are dug out in March, and the planting is usually performed at the end of April. In regard to the one-year-old rhizome, three-year-old fragments show the earliest sprouting and the highest number and mass of stems (Khan et al., 2011).

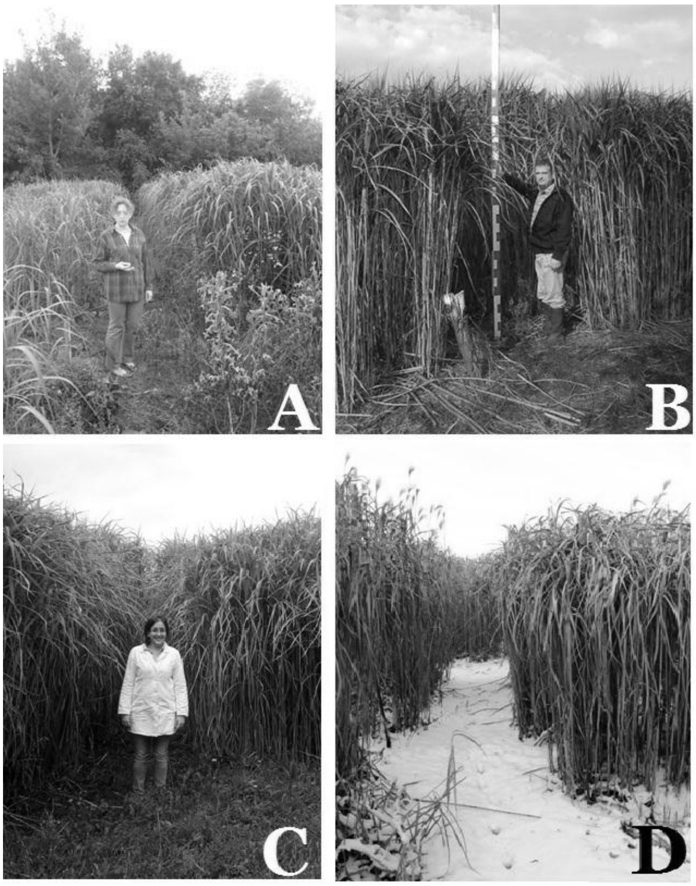

Figure 1. The authors of the study in the experimental field of INEP, Zemun (the 2016/2017 season): A) June (average crop height of 1.7–1.8 m); B) September (3.2 m); C) December (3.0 m); D) February (2.7 m). A decrease in biomass height was due to lodging caused by the snow cover.

Planting density was 2 rhizomes m^{-2}. Only in the first cultivation season (2008), weed elimination and irrigation were applied, when necessary, in order to provide optimal conditions for growth and development of the planted crop. The fertilization was performed each year by applying 667 kg NPK 15:15:15 ha^{-1} mineral fertilizers (100 kg N ha^{-1} + 100 kg P_2O_5 ha^{-1} + 100 kg K_2O ha^{-1}) immediately before crop sprouting (between April 1 and 10). Harvest was performed each year in February by mowing. Biomass yield was weighed immediately after harvesting (fresh mass). Samples of above-ground biomass from each treatment were collected for determination of average water content. After 72 h of drying at 60–70°C and subsequent cooling, the dry mass was weighed and water content and dry mass were determined.

The experiment lasted for 10 years. In the first season, the following parameters were monitored: sprouting, crop height, number of shoots (stems) and crop overwintering (rhizome freezing). In the second season, crop height was measured. Values presented in tables and figures represent arithmetic means of three replications for each treatment, with standard deviation (SD). The results were statistically analyzed (ANOVA) using the Tukey's test to check for significant differences between means ($P \leq 0.05$). Variation in yield between individual treatments (%) and the coefficient of variation (CV) of biomass yield between seasons were determined.

Results and Discussion

The first above-ground shoots were detected on May 2, 2008. However, sprouting was very irregular in the first season. It is well known that, after planting, some rhizomes will not sprout and develop, and that the initial sprouting may vary significantly. Former experiments showed that miscanthus responded favorably to fertilization, especially with nitrogen (Capecchi et al., 2013; Soare et al., 2017; Stępień et al., 2014; Xu et al., 2017; Živanović et al., 2014).

One month later, our results show comparatively high percentage of sprouting of the planted rhizomes – ≥75% (Figure 2). By the end of June 2008 (60 days after sprouting initiation) the sprouting had been completed. It amounted to 80% for 10–20 g rhizomes, while for those of 25–35 g and 40–60 g, it reached ≥92.5%. Similar results were obtained by Huisman and Kortleve (1994), who report on sprouting rates of 70–95% for rhizome fragments planted immediately after harvesting from maternal plants and 50–60% for rhizome fragments stored before planting. In the Netherlands, the researches show that the rhizomes with mass higher than 50 g, planted short time after harvest, successfully sprouted with the rates of 91–98% (Christian and Haase, 2001). Pyter et al. (2009), however, reported a sprouting rate of 60–70%.

In the second season, overall and uniform sprouting began on April 7, 2009. From the third until the ninth season, the date of sprouting outset depended on climate and weather conditions, but the sprouting mostly began around April 12 each year. This is somewhat earlier than in West Europe, where sprouting begins in the second half of April (Himken et al., 1997; Lewandowski et al., 2000).

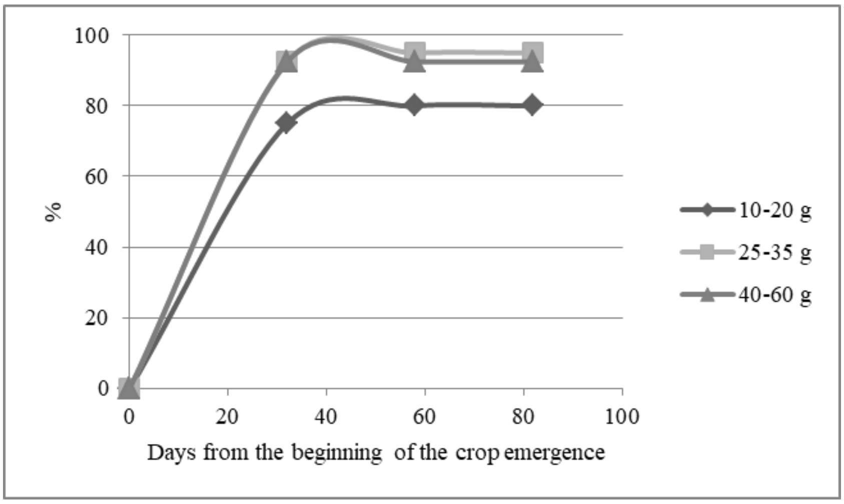

Figure 2. The percent of sprouted rhizomes in the first season (different curves represent rhizomes with different masses, $P \leq 0.05$).

Although *M.× giganteus* is a C_4 plant recognized as tolerant towards cold (Fonteyne et al., 2016), the main problem in *M.× giganteus* production is poor overwintering of rhizomes in the first season after planting. This problem is also encountered in Serbia to a lesser degree (Dželetović et al., 2013). During the winter, snow cover efficiently protects rhizomes against freezing. Lack of the snow cover, accompanied by strong frost, may cause freezing of the rhizomes in the first season. We found a comparatively high level of sprouted rhizomes of the experimental crop which had survived over the winter in the first season (Table 1). There were only 3% of frozen sprouted rhizomes among those of 10–20 g and 40–60 g during the first winter (2008/2009). An investigation conducted in Germany (Christian and Haase, 2001) revealed that, for successful crop establishment, rhizome fragments should be 200 mm long and planted at the depth of 200 mm. Good viability rates were also noticed when rhizomes of uniform size were planted at 100 mm, but overwintering rates were lower. In a Danish experiment, *M.× giganteus* rhizomes were separated into two groups, according to size. Overwinter survival of small (length <10 cm) and larger rhizomes (length >10 cm) was 34% and 82%, respectively (Christian and Haase, 2001).

Table 1. Frozen rhizome ratio during the first winter after planting.

Mass of the planted rhizomes	Number of sprouted rhizomes (±S.D.)	% of sprouted rhizomes	Number of frozen rhizomes (±S.D.)	% of frozen rhizomes
10–20 g	32.0±2.6	80.0 [b*]	1.0±1.0	3.1 [b]
25–35 g	38.0±2.0	95.0 [a]	0.3±0.6	0.8 [a]
40–60 g	37.0±2.6	92.5 [b]	1.0±1.0	2.7 [b]

*Different small letters within the same row indicate significance at the 0.05 level.

In the first season, the average stem number (Figure 3) increased most rapidly in the plots with the highest mass rhizomes. According to Khan et al. (2011), this is to be expected considering that there is a positive linear correlation between rhizome fragment mass on the one hand and stem number and fresh mass on the other. However, in an investigation conducted by Easson et al. (2010) in the Northern Ireland, where rhizome fragments weighing 26, 76 and 204 g on average were planted at the beginning of May, at the depth of 7.5 cm, it was found that the number of stems increased with the decrease of the mass of the planted rhizomes from 204 g to 26 g in the first season. Similarly, the same tendency continued in the second and third seasons. Besides, Easson et al. (2010) found that the increase of stem number resulted in a significant increase of dry matter yield regardless of the time of harvest.

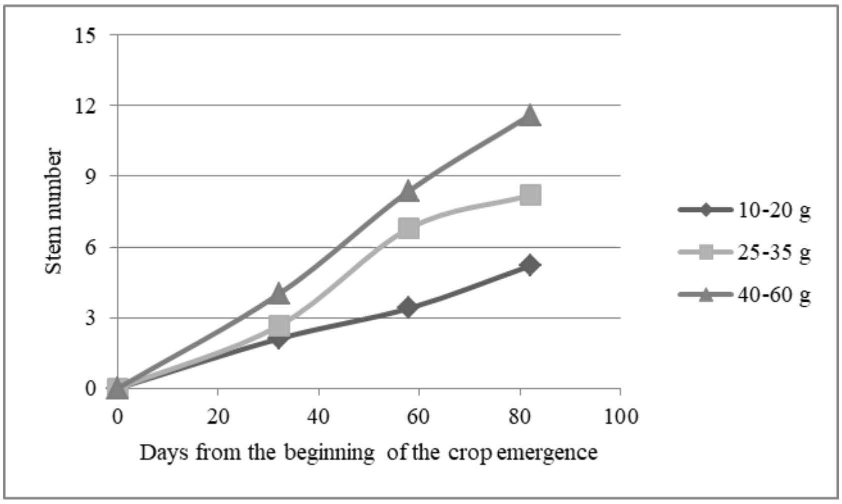

Figure 3. The average stem number per m^2 in the first season (different curves represent rhizomes with different masses, $P \leq 0.05$).

In the first season of this study, rhizomes with masses of 25–35 g and 40–60 g produced the crop of the approximately same height (Figure 4). Rhizomes with the very low mass produced plants lower by 10–20 cm. This tendency continued in the second season (Figure 5), but the difference was less pronounced. *M.× giganteus* is characterized by the crop establishment stage during which the yield is increased each year. This is followed by the maximal yield stage with variable duration. Establishing stage duration depends strongly on the method of the establishment (Lesur et al., 2013) and it can last 2–5 years (Price et al., 2004). Based on results presented in Table 2, maximum yields were obtained in the fourth and the ninth season. Obtaining high yields started from the third season. On the basis of the results of Clifton-Brown et al. (2004), the region of the West Balkans (South-East Europe) is considered to be favorable for obtaining high biomass yields of miscanthus (20–40 Mg dry matter per hectare).

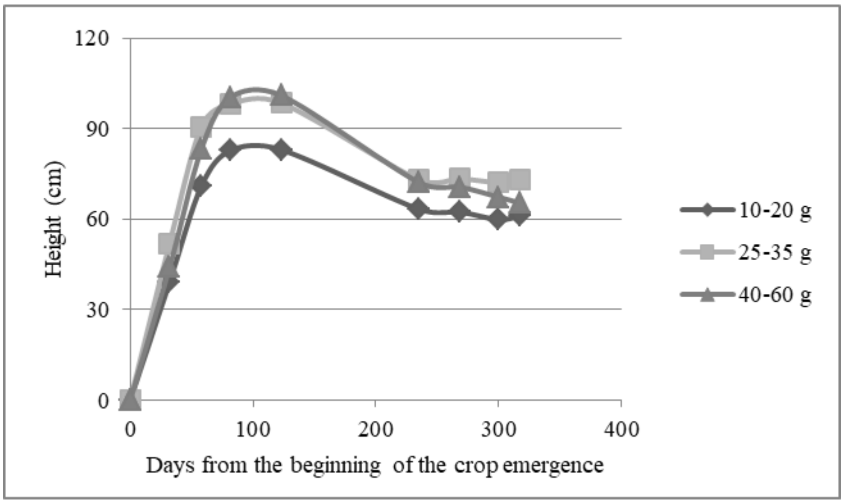

Figure 4. Average heights of the experimental crops in the first season (different curves represent rhizomes with different masses, $P \leq 0.05$).

In the first season, very low above-ground mass yields were achieved, about 1 Mg ha^{-1}. This is mainly ascribed to undeveloped root system of miscanthus (Dželetović et al., 2013). During the first season, miscanthus develops a loose root system, with the original rhizome in the center. In the second season, a dense system of lateral roots is formed together with a great number of new rhizomes (Dželetović and Glamočlija, 2015). Humentyk et al. (2013) found that, in the first season when the mass of the planted rhizomes was 20–30 g, at the end of the vegetation season, the root system mass amounted to 471 g (the 18-fold increase), while with the rhizomes of 90–120 g, the total root system mass amounted to 664 g (the 6-fold increase). On the other hand, Pyter et al. (2010) did not find a significant influence of rhizome size on the production of above-ground biomass. The initial rhizome mass of 60–75 g produced approximately 33% higher above-ground biomass than other rhizomes, which suggests that the optimal rhizome mass is within this range (Pyter et al., 2010). In our experiment, biomass yield in the second year of growth, with rhizomes of different masses, ranged from 5.5 to 8.1 Mg ha^{-1}.

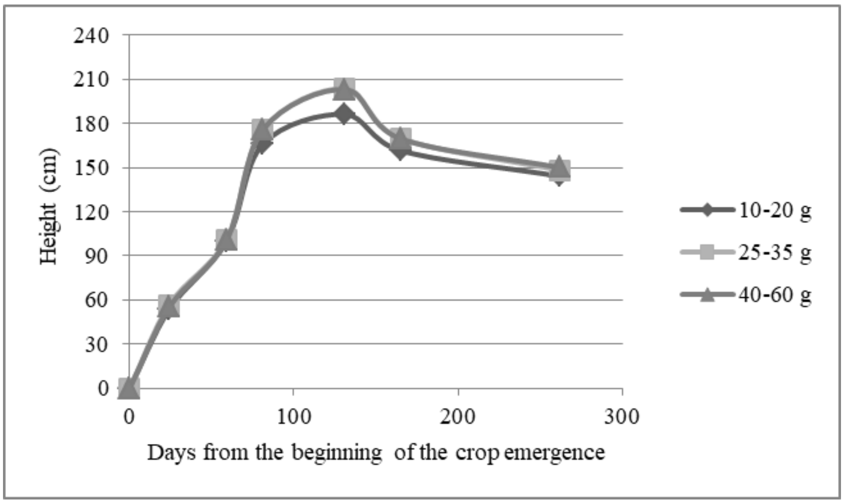

Figure 5. Average heights of the experimental crops in the second season (different curves represent rhizomes with different masses, $P \leq 0.05$).

The stage of maximal yields (stage of mature plantation, seasons 3–10) was characterized by significant seasonal differences in above-ground biomass yields, from 14.24 to 37.38 Mg DM ha^{-1} (Table 2). Variations as big as those, with some deviations from mean values for the seasons 3–10 achieving ±32%, occurred most probably due to varying weather conditions in individual seasons. Namely, at appropriate nitrogen supply, a maximal yield increase is achieved when water is not a limiting factor (Cosentino et al., 2007). Drought can cause a significant reduction in the yield of miscanthus crop (Kørup et al., 2018). Water supply from atmospheric precipitations exerts a powerful influence on above-ground biomass yield in agro-ecologic conditions characteristic for the wider Belgrade region (Dželetović et al., 2014).

Average above-ground mass yield of 23.02–25.85 Mg DM ha^{-1}, which was obtained in the seasons 3–10 (Table 2) falls within the range recorded in the West Balkans: 18.23–29.13 Mg DM ha^{-1} after November harvests at 3 locations in Croatia (Bilandžija et al., 2016); and 11.26–28.29 Mg DM ha^{-1} after February harvests at two locations in the wider region of Belgrade, Serbia (Dželetović et al., 2014). On eroded claypan soils, economically marginal for grain crops, Yost et al. (2017) obtained winter biomass yield from 13.3 to 23.8 Mg ha^{-1}, which was comparable to more productive soils. In a 12-year field trial that was conducted in southwest Germany, with N fertilization, *M.*× *giganteus* produced 18.3 Mg $ha^{-1} yr^{-1}$, and 13.6 Mg $ha^{-1}yr^{-1}$ without N fertilization (Xu et al., 2017). Besides, our results show that the coefficient of variation for a season (CV≤0.05) decreased with the aging of the plantation. Variability among the yields under different treatments also changed with the age. During the establishing stage, the lowest standard deviation was found with the rhizomes of 40–60 g, while during the mature plantation stage (seasons 3–9) the same rhizomes actually displayed the highest standard deviation of the yields (Table 2).

Table 2. Mean yield of above-ground biomass of miscanthus established by planting rhizomes of different masses (Mg ha^{-1} DM ± S.D.).

Season	Rhizome mass		
	10–20 g	25–35 g	40–60 g
1	0.63±0.06[b*]	0.96±0.08[b]	1.05±0.05[b]
2	5.53±0.44[b]	7.60±0.46[b]	8.12±0.32[a]
3	24.77±1.49[b]	27.48±1.38[b]	25.11±1.01[a]
4	31.77±1.62[b]	31.99±1.64[b]	26.85±1.64[b]
5	18.45±0.72[a]	28.66±0.74[a]	16.50±0.86[b]
6	18.27±0.55[a]	19.10±0.56[a]	16.18±0.48[a]
7	31.24±1.22[a]	32.19±1.28[a]	28.74±1.40[a]
8	16.56±0.37[a]	19.46±0.42[a]	17.93±0.38[a]
9	31.54±1.06[a]	37.38±1.28[a]	35.29±1.21[a]
10	14.24±1.06[b]	20.58±1.18[b]	17.60±0.99[b]
Mean yield of above-ground biomass in the seasons 3–10	23.35±7.38	25.85±7.36	23.02±7.04
Yield index of base rhizome mass of 40–60 g (seasons 3–10)	101.4%	112.3%	100.0%
Statistical dispersion (variability) of the yields among different treatments in the seasons 1–10 (%)	162.0	123.3	100.0
Statistical dispersion of the yields among different treatments for the seasons 3–10 (%)	120.6	91.2	100.0

[*]The coefficient of variation (CV) within a season: a) CV≤0.05; b) 0.05<CV≤0.10.

The existing cropping procedure for planting rhizomes requires the use of modified potato planters (Dželetović, 2012; MAFF, 2001). Miscanthus rhizomes that are heavier are generally of irregular shape, thus cannot be inserted into standard holes of potato planters. It is not uncommon for rhizomes to get stuck in the holes thus slowing down the planting process even when the wider holes (existing holes are either replaced or adapted) in planters are used.

Our results justify the use of low mass rhizomes in the establishment of *M.* × *giganteus* crops. Technically and practically, the use of smaller rhizomes (25–35 grams) significantly simplifies the process of establishing this crop. Furthermore, by using low mass rhizomes, the planting process will be faster, which also contributes to lowering the cost of crop establishment.

Conclusion

Plantation establishment lasted for two years. Out of the total number of planted rhizomes, the least successful plantlet emergence was noticed with very low mass rhizomes, while the emergence with low mass and medium mass rhizomes was better. During the plantation establishing stage, number of stems, crop height and above-ground biomass yield of *M.× giganteus* were optimal with the rhizomes with the highest mass (40–60 g).

However, in mature plantation, high yields of above-ground biomass can also be achieved with the rhizomes with lower mass. With the highest biomass yield (yield of above-ground biomass), the crop established with rhizomes of 25–35 g clearly stood out. Our results support the use of rhizomes that are of relatively lower mass (25–35 grams) for establishing miscanthus crops.

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UTICAJ MASE RIZOMA KORIŠĆENIH PRI ZASNIVANJU USEVA NA PRINOS BIOMASE *Miscanthus* × *giganteus*

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R e z i m e

Cilj našeg istraživanja je bio da procenimo uticaj mase rizoma bioenergetskog useva *Miscanthus* × *giganteus* na uspešnost zasnivanja i prinos biomase tokom prvih 10 godina gajenja. Ogledni tretmani su obuhvatili 3 mase rizoma: (1) 10–20 g (veoma male); (2) 25–35 g (male); i (3) 40–60 g (srednje mase). Gustina sadnje je bila 2 rizoma m^{-2}. Žetva košenjem celokupne nadzemne biomase izvođena je svake godine u februaru. Od ukupnog broja posađenih rizoma najslabije nicanje zabeleženo je kod rizoma najmanje mase. U prvoj godini gajenja najveći broj stabala i najveću visinu useva zabeležili smo u tretmanima sa najvećom masom rizoma. Međutim, u drugoj godini gajenja visina useva sva tri tretmana bila je približno ista. U prve dve godine gajenja najveću biomasu prinosa ustanovili smo u tretmanima sa najvećom masom rizoma. Iako su u fazi zasnivanja useva analizirani parametri bili najbolji sa rizomima mase 40–60 g, visoki prinosi nadzemne biomase od treće godine gajenja mogu se dobiti korišćenjem rizoma manjih masa. Jasno se ističe usev zasnovan sa rizomima mase 25–35 g sa najvećim prinosom biomase (25,85±7,36 Mg SM ha^{-1}).

Ključne reči: prinos biomase, zasnivanje useva, *M.* × *giganteus*, masa rizoma.

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THE YIELD AND GROWTH CHARACTERISTICS OF THYMUS (*Thymus daenensis L.*) TREATED WITH DIFFERENT FERTILIZERS AND PLANT DENSITIES

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Abstract: To study the effect of plant density and different nutritional systems (chemical, biological, and integrated) on the quantitative and qualitative performance of *Thymus daenensis* L. in Mahidasht Agricultural Training Center, Kermanshah/Iran, in 2017, an experiment was conducted in a split-plot design based on a randomized complete block with four replications. The first variable involved two planting distances in the row of 15 and 30 cm (the main factor), and the subsidiary factor comprised four different nutritional systems including control (no-fertilizer), chemical (100 kg superphosphate, 100 kg potassium sulfate, 150 kg urea per ha), biological (8 tons of cattle manure/ha), and integrated (50% cattle manure + 50% chemical) fertilizers. The results showed that the integrated fertilizer treatment produced the highest shoot dry weight (789.1 kg/ha), essential oil content (3.35%) and root length (15.97 cm). The integrated fertilizer treatment along with the 30-cm planting density resulted in the highest essential oil content of 3.35%. The results of this project have suggested that the integrated fertilizer and the 30-cm planting interval is the optimal treatment in thymus production due to the higher chemical fertilizer efficiency and better crop quality.

Key words: *Thymus daenesis L.,* plant density, integrated fertilizer, biological fertilizer, chemical fertilizer.

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Introduction

Optimum planting density in medicinal plants is considered as a method that guarantees the quality and quantity of secondary metabolites in different steps of planting, processing, and harvesting (Griffe et al., 2003). The higher crop and essential oil content in medicinal plants along with the necessity of the lowest chemical residue contamination of the end-product have been the major concern of farmers during production and processing procedures. Therefore, it seems that medicinal plant performance in response to biological and integrated fertilizers (biologic + chemical fertilizers) should be taken into careful consideration.

Production of medicinal plants using natural fertilizers such as animal manure seems promising (Jahan et al., 2007). In a study on thymus by Safaei et al. (2014), the positive effects of manure application on maximizing the shoot and essential oil yield were reported. They declared that chemical fertilizer increased essential oil content of the garden thymus. The reproducible natural fertilizers have shown high performance in promoting the biological activities in soil and plant interactions leading to the modification of soil chemical and physical properties in stressed conditions. Sharifi Ashoorabadi et al. (2001) reported that application of vermicompost of around 20 t/ha in cultivating parsley flower showed a positive and significant effect on growth index and absorption of macro-nutrients. In another research, the results showed that biological fertilizer in Ajwain (*Trachyspermum ammi*) significantly influenced some traits such as biological functions, seed production, and essential oil content (Ghilavizadeh et al., 2013). In research conducted by Naghdi Badi et al. (2003), the significant effect of different planting densities and planting dates on the qualitative and quantitative performance of essential oil ingredients in thymus was reported. The maximum biomass, essential oil content and thymol were obtained at the planting interval of 15 cm in the last harvest. The results from another study by Heydari Zoolah et al. (2004) on cumin in the rainfed farming system in Kermanshah/Iran indicated that seed yield was influenced by date and plant density. El-Gendy et al. (2001) reported that the increment in planting interval increased the shoot number, wet and dry weights as well as essential oil content, while significantly decreased the plant height. The purpose of this study was to determine the optimal density of *Thymus daenensis* using different fertilizing systems to achieve the best qualitative and quantitative yield.

Materials and Methods

This study was conducted in Mahidasht Agricultural Training Center, Kermanshah/Iran, in 2017. The experiment was conducted in a split-plot mode based on a randomized complete block design with four replications. The main treatment comprised planting intervals in rows including distances of 15 and 30 cm (indicating plant density) and subsidiary treatments involved four different fertilizing systems comprising control (no-fertilizer), chemical (100 kg superphosphate, 10 kg potassium sulfate, 150 kg urea 46% per ha based on the soil test), biological (8 t/ha of cattle manure based on the soil test) and integrated (50% cattle manure + 50% chemical fertilizer) fertilizers. The process of seedbed preparations included plowing, disking, softening and plotting which took place on 17 October, 2017. Before cultivation, the soil was sampled at a depth of 30 cm and the chemical and physical characteristics were determined using standard experimental methods (Sharafaldin Shirazi and Fazeli, 2015). After seedbed preparation, a furrow irrigation system was set up in experimental plots of 1.5 (length)×2 (width) m dimensions with 4 planting lines (50 cm apart) in each plot. Uniform natural seedlings (from a rangeland in Kermanshah) were retrieved and planted by hand at a depth of 5 cm in each row within the experimental plots. The planting space in each row was either 15 or 30 cm according to the corresponding treatments. The seedlings were irrigated immediately after planting. Irrigations were repeated at 5-day intervals until the start of the raining season. The agronomic operations during the growing period included weed control by hand with no chemical pesticide or herbicide application (Safaei et al., 2014). The chemical fertilizers including superphosphate, potassium sulfate and one-third of urea as well as cattle manure (in corresponding treatments) were applied before land preparation. The rest of the urea fertilizer was applied in two stages (with the first irrigation and one month after the seedlings were planted) (Safaei et al., 2014). After plant establishment and growth, 6 representative bushes from the middle row from each experimental plot (considering a marginal effect) were randomly selected and marked by red signs to measure the agronomic traits. The studied traits were measured at different growth stages which included the bush height, number of branches per bush, wet and dry weights, aerial organ volume, leaf chlorophyll, and essential oil content.

To measure the essential oil content, 50 g of plant powder was tested using a Clevenger apparatus (the essential oil content was measured in percent). The aerial organ volume of 10 bushes per experimental plot was measured in 1000-ml graduated cylinders and the mean was considered as aerial organ volume (Feiziasl et al., 2014). The chlorophyll was measured using the method of Arancon et al. (2004) by a spectrophotometer apparatus. About 0.1 g of fresh leaves was weighted by a digital balance (with 0.001-gram precision). The samples were rubbed in a crucible using 15 cc acetone 80%. Then the material was passed through filter paper and centrifuged at 4000 rpm for 10 min to remove the solvent. Finally, chlorophylls a and b were measured in 663 and 645nm by a spectrophotometer, respectively.

The test of normality was done before variance analysis using SPSS16. The variance analysis was conducted based on a randomized complete block design and the mean comparison was completed by Duncan's multiple range test at 5% and 1% probability levels using SAS. The figures were prepared in EXCEL and interpreted.

Results and Discussion

Plant height

The results of ANOVA showed that simple effects of planting densities and fertilizing systems were significant on plant height at 5% and 1% levels, respectively (Table 1). The simple effects of fertilizing systems (Figure 1) showed a significant increase in plant height for chemical fertilizer (28.0cm) and integrated fertilizer (25.9cm) compared to the control (21.2cm).

Table 1. ANOVA for *Thymus daenensis* measured characteristics.

		M.S				
S.O.V	df	Plant height	Root length	Chlorophyll a	Chlorophyll b	Dry biomass
Rep	3	6.58ns	1.3ns	0.000012ns	0.000000417ns	0.850ns
A: Planting density	1	38.72*	203.5**	0.000012ns	0.00001ns	0.435ns
E	3	7.82	4.1	0.000012ns	0.000015	0.24
B: Fertilizing system	3	95.01**	13.8**	0.00004ns	0.00000018ns	4.53**
Interaction (AB)	3	13.11ns	9.1ns	0.000012ns	0.00000083ns	0.5ns
E: (Error)	18	3.03	1.48	0.000012ns	0.000012	0.157
CV (%)	-	7.20	8/72	16/16	25	10/58

ns: non-significant; *Significant at p≤0.05; **Significant at p≤0.01.

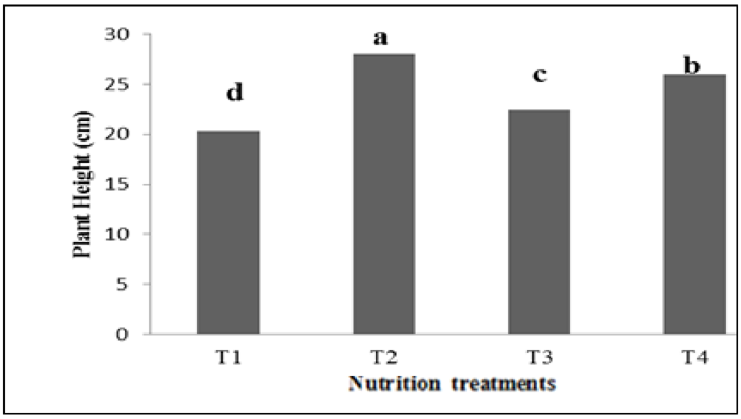

Figure 1. Effects of different fertilizer treatments on plant height.
T_1: Control, T_2: Chemical fertilizer, T3: Biological fertilizer (manure), and T4: Integrated fertilizer (50% chemical + 50% biological fertilizer).

The planting interval in the row of 30 cm produced significantly taller plants (22.9cm) compared to the 15-cm (26.1 cm) planting space (Figure 2). The biological fertilizer increased the height of plants compared to control, which was due to increased length of internodes (Moghaddam et al., 1997). The integrated fertilizer (cattle manure + chemical fertilizers) showed synergistic effects on plant and soil properties (Sharifi Ashoorabadi et al., 2001; Akbarinia et al., 2010).

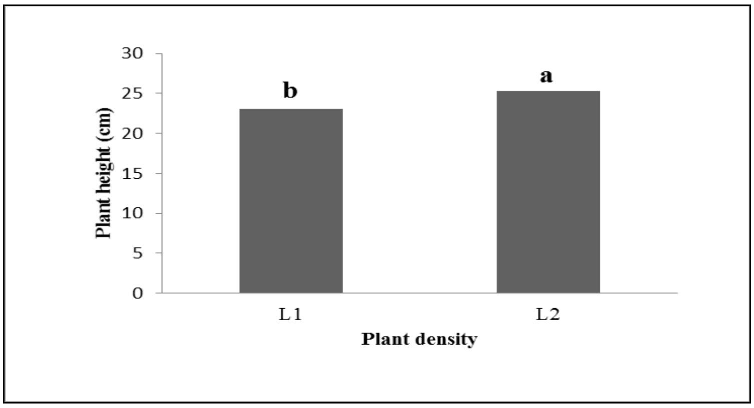

Figure 2. Effects of planting density on plant height.
L1 and L2 (planting intervals of 15 and 30 cm in the row, respectively).

The integrated fertilizer provided the possibility of absorption of essential nutrients in early stages of growth. In the vegetative growth stages, animal manure provided more micro and macro nutrients to support better performance of the plants (Akbarinia et al., 2010; Kandeel et al., 2002). The results of a study on chamomile showed that high planting density could result in higher competition among neighboring plants for light. Higher planting density not only resulted in no beneficial effects on the final size of the plants, but it also decreased the qualitative and quantitative plant characteristics (Franke and Schilcher, 2005; Salamon, 2007).

Root length

Simple effects of planting density and fertilizer treatments were significant on root length ($p<0.01$). The results in Figures 3 and 4 showed that the integrated fertilizer and a planting density of 30 cm with the root lengths of 16 and 16.5 cm, respectively, most positively affected root growth compared to other treatments. Anderson and Impiglia (2002) and Pedersen et al. (2009) reported that the maximum impact of nitrogen application was seen in the root length, while its least impact was noticed in dry root weight among the studied traits. They explained that nitrogen increased the growth of some root traits such as length, number, fresh and dry weights as well as the volume. The results of this study on nitrogen application correspond with the results of Hoad et al. (2004) on wheat.

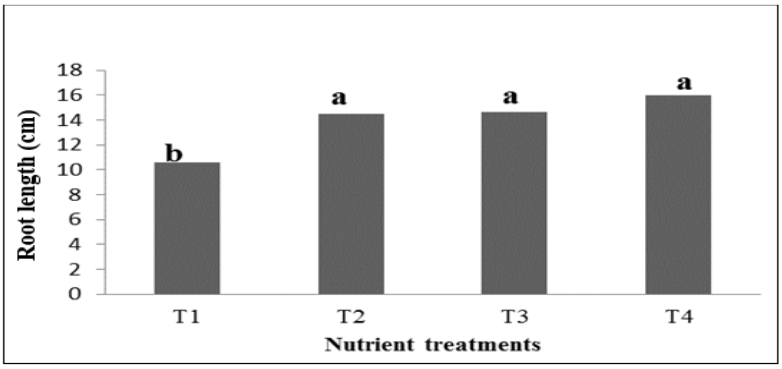

Figure 3. Effects of different fertilizing treatments on root length.
T_1: Control, T_2: Chemical fertilizer, T3: Biological fertilizer (manure), and T4: Integrated fertilizer (50% chemical + 50% biological fertilizer).

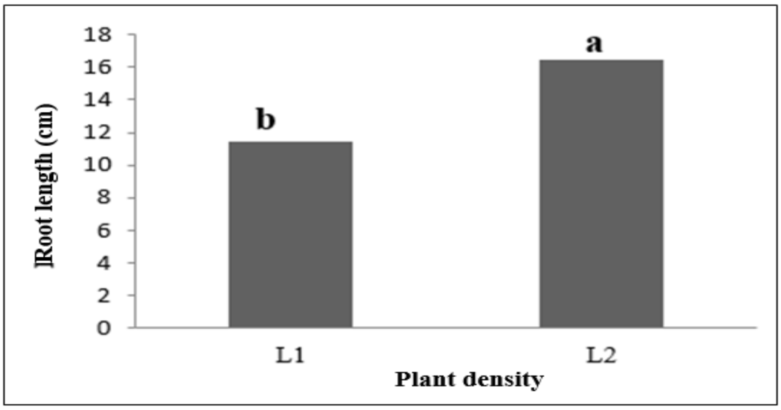

Figure 4. Effects of plant density on root length.
L1 and L2 (plant densities of 15 and 30 cm respectively).

Chlorophylls a and b

No significant effects of planting density, fertilizer treatments or their interactions were observed in chlorophylls a or b. Kafi et al. (1997) indicated that increased plant density decreased the photosynthesis rate because the increased leaf surface area caused more shade on the lower leaves via decreasing light absorption efficiency. They explained that increased plant density caused a kind of internal competition for light, space, water, and fertilizer causing the less chlorophyll content.

Shoot dry weight per plant

The simple effects of planting density and fertilizer treatments were significant on shoot dry weight ($p<0.01$) (Table 1). The integrated fertilizer treatment increased biomass per plant (4.38 g) by 64% compared to control (2.67 g) (Figure 5). Arancon et al. (2004) have explained that the soils treated with cattle manure suggest higher population of micro-organisms, available phosphorus, potassium, calcium, magnesium, and nitrate compared to soils treated with chemical fertilizers. Feiziasl et al. (2014) reported that the fresh and dry weights as well as shoot volume in the 90 kg N_2/ha treatment were higher than in the 30 kg N_2/ha treatment. Solomon (2007) reported that increased density resulted in increasing the dry weight of chamomile to 1200 kg/ha.

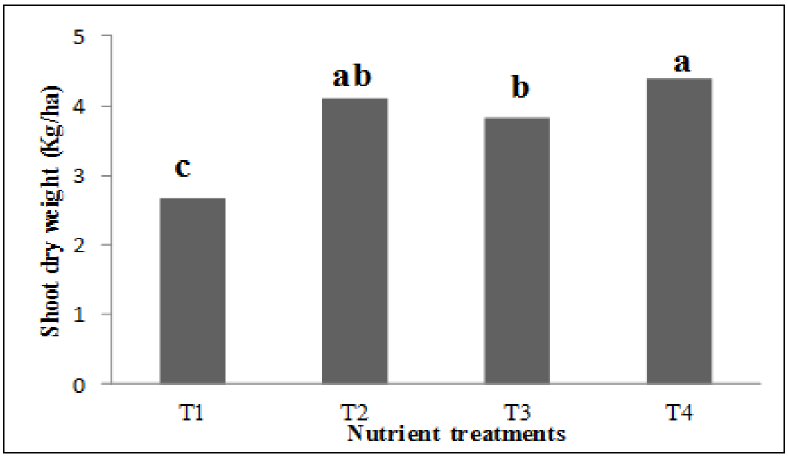

Figure 5. Effects of different fertilizing treatments on shoot dry weight.
T_1: Control, T_2: Chemical fertilizer, T3: Biological fertilizer (manure), and T4: Integrated fertilizer (50% chemical + 50% biological fertilizer).

Shoot yield per hectare

The simple effects of planting density and fertilizer treatments were significant on shoot dry weight ($p<0.01$). Integrated fertilizer application produced maximum shoot dry weight in a hectare (78.9 kg/ha), while the least shoot dry matter production was recorded in control (48.1 kg/ha). Arancon et al. (2004), in a research on the pumpkin, showed that animal manure could increase plant biomass compared to control. As the amount of manure application increased, biomass production followed a linearly increasing trend. (Figure 6). These results were supported by other researchers on *Solanum sp.* (Feiziasl et al., 2014). Organic fertilizer made positive changes in physical and chemical characteristics of soil and promoted the availability of the required nutrients for plants during the growing season (Khoramdel et al., 2008). It is reported that the slow releasing characteristic of animal manure prevents nutrients (N in particular) from leaching by excess water (Kolata et al., 1992). The chemical fertilizer had no significant impact on plant performance which could be explained by higher nitrogen leaching to deeper soil layers. Our results correspond to the findings of Khoramdel et al. (2008) working on biologic fertilizer in blackcurrant.

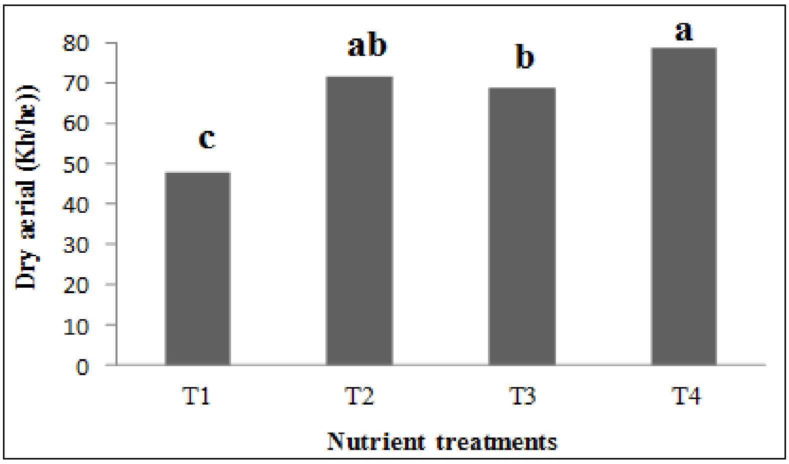

Figure 6. Effects of different fertilizing treatments on shoot dry yield per hectare.
T_1: Control, T_2: Chemical fertilizer, T3: Biological fertilizer (manure), and
T4: Integrated fertilizer (50% chemical + 50% biological fertilizer).

Essential oil content

The effect of fertilizer treatment was significant on essential oil content ($p<0.01$). Among the fertilizer treatments, the integrated fertilizer treatment produced 2.2 times higher essential oil content (3.35%) compared to control (1.53%) (Figure 7). No significant difference was observed among the plant densities in our project. However, based on a study on thymus, by increasing the planting density, the shoot biomass and essential oil content per unit area significantly increased (Ghilavizadeh et al., 2013). Baranauskiene et al. (2003) studied the effect of chemical fertilizer on thymus and indicated that essential oil content ingredients showed no significant response to different treatments. It seems that, in aromatic plants, the growth and performance of the essential oils are affected by various environmental factors such as temperature, water stress, salinity, nutrient deficiencies, and intra-basal competition.

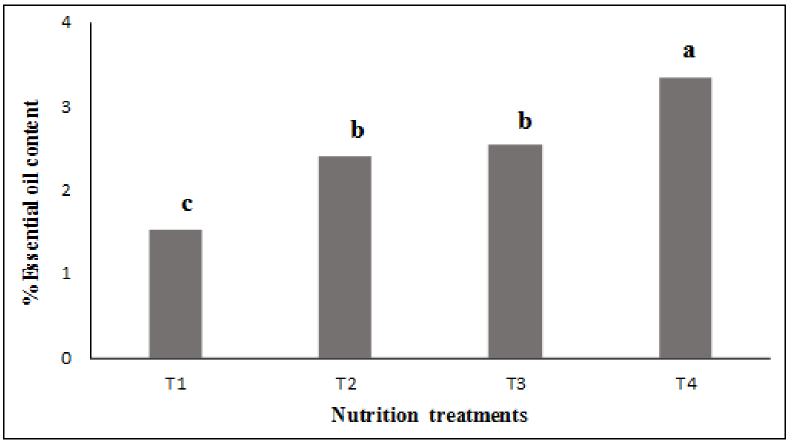

Figure 7. Effects of different fertilizing treatments on essential oil content.
T_1: Control, T_2: Chemical fertilizer, T3: Biological fertilizer (manure), and T4: Integrated fertilizer (50% chemical + 50% biological fertilizer).

Root dry weight

The effect of fertilizer treatment was significant on root dry weight ($p<0.01$), while planting density and its interaction with fertilizer treatment showed no significant impact. The results indicated that the lower plant density (30-cm planting interval in the row) and the chemical fertilizer produced the maximum root dry weight (3.0 g and 3.5 g dry root/plant, respectively) (Figures 8 and 9). Feiziasl et al. (2014) indicated that morphological characteristics of root could be changed with soil physical characteristics, soil nitrogen and climatic conditions, therefore, the optimal amount of fertilizers, especially nitrogen, could significantly improve plant growth.

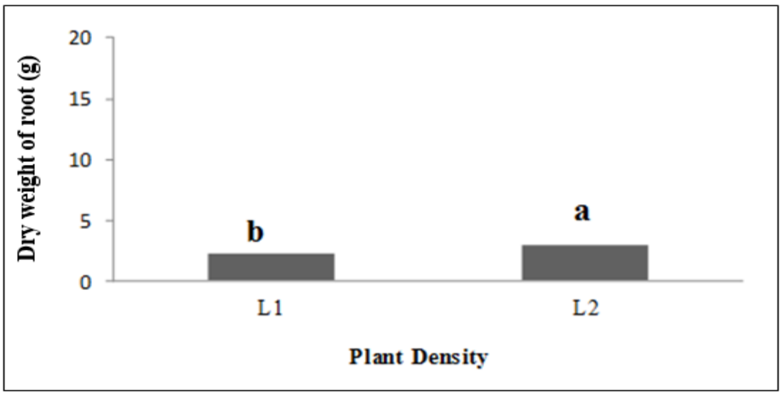

Figure 8. Effects of plant densities on the root dry weight.
L1 and L2 (plant densities of 15 and 30 cm respectively).

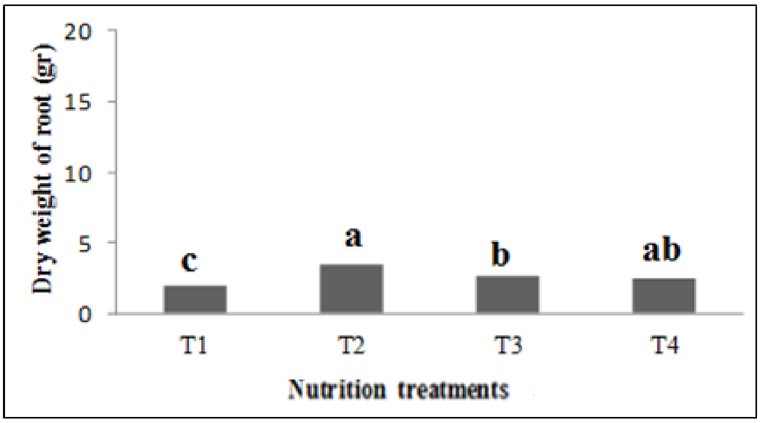

Figure 9. Effects of the different fertilizing treatments on root dry weight.
T_1: Control, T_2: Chemical fertilizer, T3: Biological fertilizer (manure), and T4: Integrated fertilizer (50% chemical + 50% biological fertilizer).

Root/shoot ratio

The results indicated that simple effects of planting densities and fertilizer treatments were not significant on root/shoot ratio. Most of the plants responded to water stress by increasing the proportion of photosynthetic materials, which promoted the better root growth (Figure 10). A higher root/shoot ratio warrants more water availability for plants under water stress conditions (Kafi and Mahdavi Damghani, 1997). It seems that the morphological characteristics of the roots changed with soil physical conditions, soil nitrogen, and climate. Therefore, the optimal amount of fertilizers, especially nitrogen, could be critical in plant growth and development.

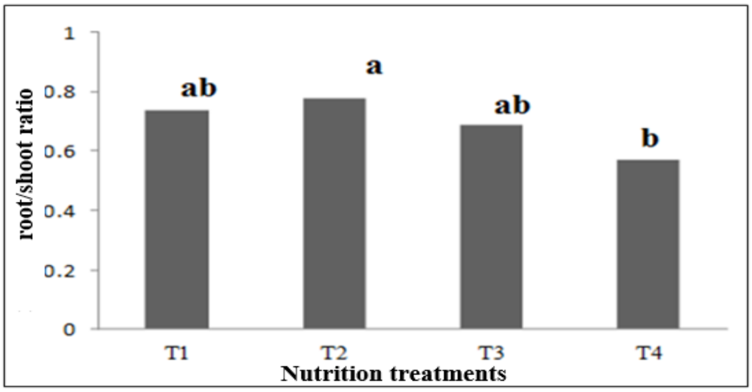

Figure 10. Effects of different fertilizing treatments on root/shoot ratio.
T_1: Control, T_2: Chemical fertilizer, T3: Biological fertilizer (manure), and T4: Integrated fertilizer (50% chemical + 50% biological fertilizer).

Aerial organ volume

The results indicated significant ($p<0.01$) simple effects of planting densities and fertilizer treatments on aerial organ volume (Table 2). The results indicated that plant density of 30 cm (13.1 cm^3) and chemical fertilizer (13.7 cm^3) produced maximum aerial organ volume (Figures 11 and 12).

Table 2. Analysis of variance of different levels of nutritional treatments and planting densities on some quantitative and qualitative traits of *Thymus daenensis.*

		M.S				
S.O.V	df	Shoot dry weight	% Essential oil content	Root dry weight	Root/shoot ratio	Aerial organ volume
Replication	3	63.81ns	4862.5ns	0.22ns	0.11ns	1.75ns
Planting density	1	226.5ns	5000ns	5.03**	0.13ns	38.5**
E_a: (Error)	3	87.4	983	0.31	0.64	2.46
Fertilizing systems	3	1398.9**	13379.1**	3.9**	0.12ns	15.62**
Interaction	3	179.33ns	283.3ns	0.19ns	0.04ns	1.25ns
E_b (Error)	18	69.78	745.1	0.19ns	0.042	1.05

ns: non-significant *Significant at p≤0.05 **Significant at p≤0.01.

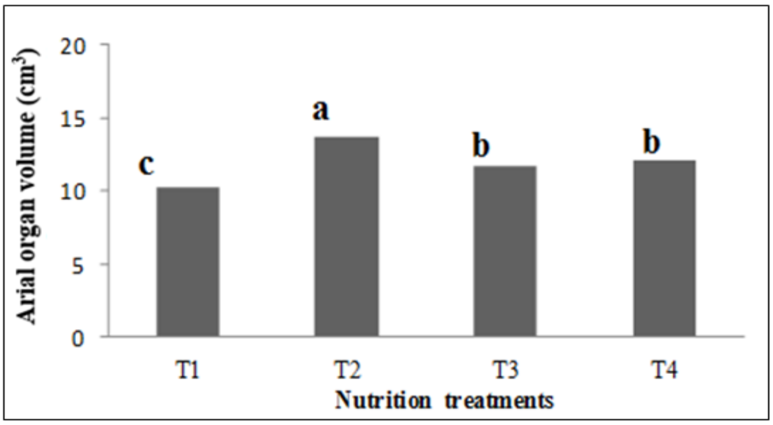

Figure 11. Effects of different fertilizing treatments on aerial organ volume.
T_1: Control, T_2: Chemical fertilizer, T3: Biological fertilizer (manure), and T4: Integrated fertilizer (50% chemical + 50% biological fertilizer).

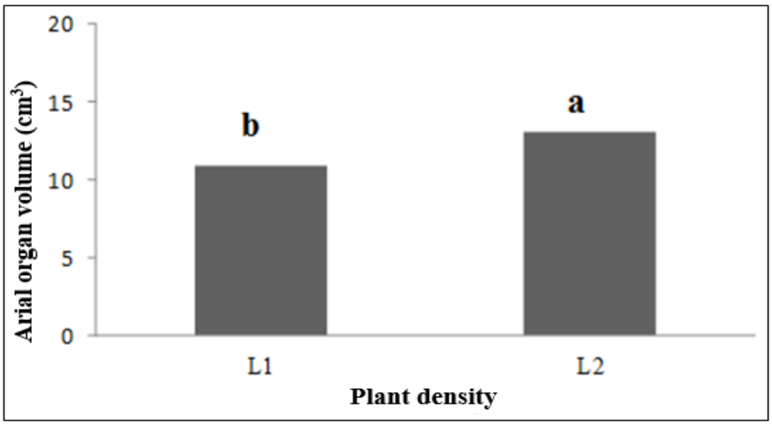

Figure 12. Effects of planting densities on aerial organ volume.
L1 and L2 (plant densities of 15 and 30 cm respectively).

Feiziasl et al. (2014) reported that the effect of nitrogen fertilizer was significant not only on fresh shoot weight but also on the aerial organ volume ($p<0.01$). Biological fertilizer in blackcurrant significantly increased plant height, leaf surface index, aerial organ volume and overall plant performance compared to control. Our results support the findings of El-Gendy et al. (2001) who have reported that by increasing the planting density, a significant increase in shoot yield is achievable. Sharifi Ashour Abadi et al. (2001) have stated that sheep manure contains micro and macro elements necessary for vital activities of the plant, which improves soil texture, increases water absorption capacity and provides a suitable environment for root development.

Conclusion

The results of this study showed that a combination of integrated fertilizer application and lower planting density (30-cm planting intervals in the row) improved the qualitative and quantitative characteristics of the thymus. It seems that the integrated fertilizer method can play an effective role in increasing the quality and quantity of thymus shoot yield. This result could be explained by the slow release of micro and macro nutrients from the manure which increased the nutrient availability and absorption efficiency in this treatment. It could be also suggested that the lower planting density may increase the essential oil content due to better light infiltration in the plant canopy.

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KARAKTERISTIKE PRINOSA I RASTA MAJČINE DUŠICE (*Thymus daenensis L.*) U ZAVISNOSTI OD ĐUBRIVA I GUSTINE BILJAKA

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R e z i m e

Kako bi se proučio uticaj gustine biljaka i različitih sistema ishrane (hemijskog, organskog i kombinovanog) na kvantitativne i kvalitativne karakteristike biljke *Thymus daenensis* L. u Poljoprivrednom centru za obuku u Mahidaštu (Kermanšah/Iran) u 2017. godini, sproveden je eksperiment podeljenih parcela zasnovan na potpuno slučajnom blok sistemu sa četiri ponavljanja. Prvi tretman je uključivao dva razmaka biljaka u redu od 15 i 30 cm (glavni faktor), a drugi faktor se sastojao od četiri različita sistema ishrane, uključujući kontrolu (bez đubriva), hemijsko (100 kg superfosfata, 100 kg kalijum sulfata, 150 kg uree po ha), organsko (8 tona goveđeg stajnjaka po ha) i kombinovano (50% goveđeg stajnjaka + 50% hemijskog) đubrivo. Rezultati su pokazali da su u tretmanu sa kombinovanim đubrivom proizvedeni najveća nadzemna suva masa (789,1 kg / ha), sadržaj eteričnih ulja (3,35%) i dužina korena (15,97 cm). U tretmanu sa kombinovanim đubrivom i razmakom u redu od 30 cm utvrđen je najviši sadržaj eteričnih ulja – 3,35%. Rezultati ovog projekta sugerišu da je kombinovano đubrivo i razmak biljaka u redu od 30 cm optimalni tretman u proizvodnji majčine dušice, zbog veće efikasnosti hemijskih đubriva i boljeg kvaliteta useva.

Ključne reči: *Thymus daenesis L.*, gustina biljaka, kombinovano đubrivo, organsko đubrivo, hemijsko đubrivo.

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MORPHO-GENETIC VARIABILITY IN F_2 PROGENY COWPEA GENOTYPES TOLERANT TO BRUCHID (*Callosobruchus maculatus*)

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Abstract: *Callosobruchus maculatus* Fab. is a major threat to cowpea production reducing the quality, quantity and market value of cowpea grains. A cheap and easy identification method would be a valuable tool in identifying and breeding resistant genotypes in the vast cowpea germplasm. Hence, the purpose of the study was to identify and evaluate the genetics of cowpea traits between resistant and susceptible plant genotypes to *C. maculatus.* Contrasting qualitative and quantitative traits in *C. maculatus* resistant and susceptible parents were evaluated in 72 F_2 progeny cowpea plants. Heritability, segregation and association of investigated traits with the *C. maculatus* resistant performance of the F_2 cowpea genotypes were evaluated to determine closely related traits with *C. maculatus* resistance. Results from the study showed high heritability for all cowpea quantitative traits except leaf petiole length. Both Mendelian inheritance and non-Mendelian inheritance were observed among qualitative traits. However, association evaluation between cowpea traits and mean bruchid development period, percentage adult emergence and oviposition preference were weak ($r < 0.5$) and not significant ($p < 0.05$). This indicates that *C. maculatus* resistance in cowpea may be attributed to factors other than morphological variations.

Key words: *Callosobruchus*, cowpeas, variability, susceptibility, resistant, morphology

Introduction

Cowpea (*Vigna unguiculata* L. Walp.) is an important warm season grain legume cultivated in over 65 countries covering Asia and Oceania, the Middle East,

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Southern Europe, Africa, southern USA and Central and South America (Singh, 2005). Over 80% of dry cowpea produce comes from three countries (Nigeria, Niger and Burkina Faso) of West Africa that cover nearly 83% of the global cowpea area (Popelka et al., 2006). For this reason, cowpea remains the primary source of income for small-scale farmers practising agriculture in dry savannah of sub-Saharan Africa (Kamara et al., 2012).

Cowpea feeds millions of people in developing worlds with an annual world-wide production estimated around 4.5 metric tonnes on 12–14 million ha (Diouf, 2011). It is favoured by farmers because of its ability to maintain soil fertility (Blade et al., 1997, Muchero et al., 2009). It is a nitrogen-fixing plant, and when used in rotation with cereal crops, it can help restore soil fertility (Sanginga et al., 2003). Similarly, it is a source of income (Singh, 2002; Timko et al., 2007), and it is used as animal fodder (Deshpande et al., 2011). In addition, comparably high yields in harsh environments where other food legumes do not thrive (Shimingani and Shimelis, 2011) have made it a crop of choice for many farmers in the sub-Sahara regions. Despite this, it has been revealed that the mean grain yield of cowpea in a typical sub-Saharan African farmer's field is about 495 kg ha^{-1}, much lower than what is obtained under experimental conditions (FAO, 2012).

Callosobruchus maculatus Fab. is considered the most important and common pest of cowpea in storage both in Africa and Asia (Deshpande et al., 2011). Infestation by this insect pest starts on the field, but heavy damage is done during storage. The larvae of the *C. maculatus* feed on the seed contents and estimates of storage losses are highly variable ranging widely from 4% to 100% due to perforations, thus reducing the degree of usefulness and making the seeds unfit either for planting or human consumption reducing its market values (Oluwafemi, 2012; Mofunanya and Namgbe, 2016).

The use of resistant cultivars is still the best method to manage *C. maculatus* infestation (Tripathy, 2016). Although only three cowpea accessions (TVu2027, TVu11952, TVu11953) have been identified to have moderate resistance to *C. maculates*, there has been a recent report showing that two of the accessions (TVu2027, TVu11952) have shown reduced resistance to *C. maculatus* damage (Amusa et al., 2014). Therefore, the need to identify and breed alternative sources of *C. maculatus* resistance to bruchid damage cannot be overestimated. Furthermore, easy identification of resistant accessions without bioassays has been difficult. Hence, the purpose of the study was to evaluate the genetics of cowpea traits between resistant and susceptible plant genotypes to *C. maculatus*, and find the association of these traits with *C. maculatus* resistance.

Materials and Methods

Collection of samples and bioassay

C. maculatus resistant (TVu11953) and susceptible (Ife Brown) cowpeas were collected for the study from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria and the Institute of Agricultural Research and Training (IAR&T), Moor Plantation, Ibadan, Nigeria respectively. They were screened for *C. maculatus* resistance to ascertain their tolerance level according to the method of Amusa et al. (2014). Seventy-two (72) F_2 segregating populations from the reciprocal crosses between TVu11953 and Ife Brown were developed for the study. The cowpea samples were verified for *C. maculatus* resistance accordingly. Mean development period (MDP), percentage adult emergence (PAE) and oviposition preference were used as measures for *C. maculatus* resistance in the study (Amusa et al., 2014).

Morphological evaluation of collected samples

Seeds of 72 F_2 segregating populations developed above were collected and planted in plastic buckets of 2-kg pots at equidistance from each other arranged in a randomised complete block design with three replications in the screen house, IAR&T, Ibadan, Oyo State (Latitude: 7º 22' 35.2" N, Longitude: 3º 50' 34.4" E). Ten (10) replicated pots of cowpea grains for each of TVu11953 and Ife Brown parent genotypes were planted alongside the 72 F_2 genotypes and normal agronomic practices were carried out throughout the duration of the study. Phenotypic evaluations of the parent cowpea genotypes (TVu11953 and Ife Brown) were done to identify variation in quantitative and qualitative traits between TVu11953 and Ife Brown genotypes according to Cowpea Descriptors of the International Board for Plant Genetic Resource (IBPGR, 1983). Significantly different traits between both parents were phenotyped on the F_1 and F_2 segregation generation plants.

Data collection and analysis

Differentiating qualitative traits between TVu11953 and Ife Brown were identified by observation while t-test was used to identify differentiating quantitative traits of cowpea measured. Differences were considered significant at the 5% significance level. Heritability evaluation was done on significantly different quantitative traits of parent cowpea genotypes measured in the F_2 progeny population according to Boopathi (2013). Qualitative traits of cowpea were subjected to the chi-square goodness of fit to determine the segregation pattern in

F_2 cowpea population and the chi-square test for independent assortment was used to determine association between qualitative traits and bruchid resistant traits.

Results and Discussion

Morphological differences between TVu11953 and Ife Brown bruchids

Differences both in qualitative and quantitative traits were observed between TVu11953 and Ife Brown parent cowpea genotypes in the study. Observable qualitative trait differences included seed shape, seed colour, pod shape, photoperiod sensitivity, flower colour and seed size (Table 1). Significant cowpea quantitative trait differences in the study included terminal leaflet length ($t = 3.11$, $p < 0.01$), leaf petiole length ($t = 2.64$, $p < 0.05$), pod length ($t = 24.23$, $p < 0.01$), pod width ($t = 3.91$, $p < 0.01$), seed length ($t = 6.52$, $p < 0.01$), seed width ($t = 4.44$, $p < 0.01$), seed thickness ($t = 3.94$, $p < 0.01$) and 100-seed weight ($t = 20.44$, $p < 0.01$) (Table 2). Cobbinah et al. (2011) have reported diverse phenotypic variations among cowpea accessions. Variations observed in this study were similar to such variations that have been reported for seed coat colour, pod shape, flower colour, flowering time, flowering initiation, terminal leaflet length, terminal leaflet width, leaf petiole length, pod length, pod width, seed length, seed width, seed thickness and 100-seed weight (Timko et al., 2007; Cobbinah et al., 2011).

Table 1. Qualitative traits of cowpea genotypes which show differences between TVu11953 and Ife Brown cowpeas.

Characters of cowpea	TVu11953	Ife Brown
Source	IITA	IAR&T
Source status	*C. maculatus* resistant	*C. maculatus* susceptible
Study status	*C. maculatus* resistant	*C. maculatus* susceptible
Seed shape	Kidney	Rhomboid
Seed coat colour	Mottle red	Brown
Pod shape	Curved	Straight
Days to the 1^{st} flowering	65 days	45 days
Days to 50% flowering	70 days	50 days
Photoperiod sensitivity	Photoperiod sensitive	Photoperiodic neutral
Flower colour	Purple	White
Seed size	Large	Small

IITA: International Institute of Tropical Agriculture, Ibadan; IAR&T: Institute of Agricultural Research and Training, Ibadan.

Table 2. Quantitative traits of cowpea genotypes which show differences between TVu11953 and Ife Brown bruchids.

Characters	TVu11953	Ife Brown	t-test
Terminal leaflet length (cm)	15.43	13.51	3.11**
Leaf petiole length (cm)	8.36	11.43	2.64*
Pod length (cm)	7.08	11.05	24.23**
Pod width (mm)	6.00	7.90	3.91**
Seed length (mm)	10.63	7.98	6.52**
Seed width (mm)	7.47	5.77	4.44**
Seed thickness (mm)	5.93	4.38	3.94**
100-seed weight (g)	26.32	15.23	20.44**

* $p < 0.05$; ** $p < 0.01$.

Segregation of qualitative traits in F_1 and F_2 cowpea populations

Segregation of cowpea seed shape

Both TVu11953 and Ife Brown were true breeding for kidney and rhomboid seed shapes respectively. F_1 generation seeds from reciprocal crosses showed that all seeds from TVu11953 mother plants had kidney-shaped seeds while rhomboid seed shape was observed in all seeds from Ife Brown mother plants. However, the F_2 seeds from TVu11953 mother plant lines were all kidney-shaped, but Ife Brown mother plant lines produced 707 kidney-shaped seeds and 601 rhomboid-shaped seeds. Furthermore, the kidney-shaped seed exhibited complete dominance on the TVu11953 mother plant line with the absence of the rhomboid-shaped seeds. Seed shape analysis from pooled F_2 sampled seeds showed a monogenic pattern of inheritance ($\chi^2(3:1) = 0.72$, $p > 0.05$) with kidney shape dominant over rhomboid shape (Table 3).

Table 3. A segregation pattern of seed shape in F_1 and F_2 cowpea generations.

Crosses (♀ + ♂)	F_1 seeds		F_2 seeds		$\chi^2(1:3)$	$\chi^2(3:1)$
	Kidney	Rhomboid	Kidney	Rhomboid		
P_1 x P_2	32	0	1025	0	-	-
P_2 x P_1	0	75	707	601	588.79**	306.12**
Total	32	75	1732	601	3016.72**	0.72

** $p < 0.01$; χ^2: Chi-square; ♀: Maternal plant; ♂: Paternal plant; P_1: TVu11953; P_2: Ife Brown.

The presence of F_1 hybrid seed shapes conforming to the seed shape of their mother plants shows the presence of a maternal influence on the inheritance of seed shape in cowpea while the segregation pattern of seed shape in the F_2 cowpea population corroborates with the work of Meena and Kumar (2014) who reported 3:1 monogenic inheritance of seed shape in F_2 segregation population of chickpea. However, the result of this study did not corroborate with the findings of Hossain et al. (2010) who reported that seed shape was controlled by two genes in soybean and chickpea and a segregation ratio of 9:7 in their study.

Segregation of cowpea seed coat colour

Seed coat colour is a major trait that affects consumer acceptability in cowpea. Its preference and use patterns differ from one region to another (Egbadzor et al., 2015). Both TVu11953 and Ife Brown were true breeding for mottled red and brown seed coat colours. Maternal effect was observed in seed coat colour segregation with F_1 seeds produced from maternal plants resembling maternal seeds. F_1 hybrid seeds from TVu11953 mother plants were all mottled in colour while seeds from Ife Brown mother plants were all brown in colour (Table 4). However, the presence of intermediates in the F_2 seed population showed that seed colour may be controlled by more than one gene.

Table 4. A segregation pattern of seed colour in F_1 and F_2 cowpea generations.

Crosses (♀ + ♂)	F_1 Seeds		F_2 Seeds			χ^2 (1:3)	χ^2 (3:1)	χ^2 (1:2:1)
	Mot	Brown	Mot	Int	Brown			
P_1 x P_2	32	0	707	318	0	1057.17**	19.84**	-
P_2 x P_1	0	75	1	706	601	588.79**	306.12**	
Total	32	75	708	1025	601	-	-	43.96**

** $p < 0.01$; χ^2: Chi-square; ♀: Maternal plant; ♂: Paternal plant; P_1: TVu11953; P_2: Ife Brown; Mot: Mottled red; Int: Intermediate colour.

F_2 seeds from TVu11953 mother plant lines produced 707 seeds with mottled red colour and 318 seeds which showed an intermediate colour. The segregation pattern of seed coat colour on both TVu11953 and Ife Brown plants significantly deviated from Mendelian segregation ratio for monogenic recessive and dominant inheritance respectively ($p < 0.01$). Similarly, dihybrid inheritance analysis of seed coat colour in pooled sampled seeds from both TVu11953 and Ife Brown mother plants also showed a significant deviation from the expected 1:2:1 ratio (Table 4). Cowpeas have been reported to show varied seed coat colours ranging from white to cream to brown to black each controlled by genes with maternal effects (Drabo et al., 1988; de Castro et al., 2013). These authors have showed that five major genes interact to produce ten different seed coat colours in cowpea. Their works have also showed that all colour genes could be recessive to give red seeds while the absence of seed coat pigmentation results in cream or white seeds. Epistasis interactions in the genes responsible for seed coat colour in cowpea have also been reported (Kongjaimun et al., 2012; Lachyan and Dalvi, 2015).

Segregation of cowpea pod shapes

Both TVu11953 and Ife Brown were true breeding for curved and straight pod shapes. The presence of curved and straight pods in hybrid plants of TVu11953 and Ife Brown mother plants respectively shows that pod shape inheritance may be maternally influenced in the F_1 generation. In the F_2 generation, both TVu11953 and Ife Brown mother plant lines produced both curved and straight pods. The presence of 111 curved and 38 straight pods in the TVu11953 mother line revealed a dominance of monogenic inheritance for curved pods over straight pods (χ^2(3:1) = 0.02, $p > 0.05$). This is similar to the works of Nwofia (2014) who reported that coiled shaped pods were dominant over the straight shape pods in the F_2 generation of cowpea. However, the pooled samples showed a pod shape segregation pattern with a goodness of fit to expected ratio of 9:7 for straight pods to curved pods (χ^2(9:7) = 3.08, $p > 0.05$) (Table 5). This signifies the presence of epistasis interaction of duplicate recessive genes for straight-shaped pods from the pooled samples in the F_2 generation pods. Uguru (1995a) reported that there were evidences that pod shape in cowpea was governed by two loci, *PP* and *VV* for coiled and straight pod shapes, the former being dominant and epistatic over the latter.

Table 5. A segregation pattern of pod shape in F_1 and F_2 cowpea generations.

Crosses (♀ + ♂)	F_1 pods		F_2 pods		χ^2 (1:3)	χ^2 (3:1)
	Curved	Straight	Curved	Straight		
P_1 x P_2	21	0	111	38	194.69**	0.02
P_2 x P_1	0	45	25	174	16.42**	413.75**
Total	21	45	136	212	36.80**	239.46**

** $p < 0.01$; χ^2: Chi-square; ♀: Mother (recipient) plant; ♂: Father (donor) plant; P_1: TVu11953; P_2: Ife Brown

Segregation of cowpea photoperiod sensitivity

The time of flowering is an important agronomic trait as it affects both adaptation of a variety to a particular agro-ecological zone and also its productivity (Ishiyaku et al., 2005). The onset of flowering in cowpea is modulated by a photoperiod which has a significant effect on phenology in all cowpea genotypes (Nuhu and Mukhtar, 2013). Some authors have indicated the photoperiod to be the most important environmental variable affecting flowering time and that most cultivated cowpeas in west Africa were photoperiod sensitive (Craufurd et al., 1996). TVu11953 was observed to be photoperiod sensitive initiating its flowers only between October and February while Ife Brown was photoperiod insensitive, flowering throughout the year of planting regardless of planting time. The initiations of flowers in TVu11953 and Ife Brown were averagely 65 and 45 days respectively after sowing. This corroborates with the works of Craufurd et al. (1996) and Manggoel and Uguru (2011) who stated that cowpea genotypes with mean first flowering greater than 45 days were photoperiod sensitive while those that flowered less than 45 days were photoperiod insensitive or neutral.

Table 6. A segregation pattern of photoperiod sensitivity among F_1 and F_2 cowpea generations.

Crosses (♀ + ♂)	F_1 plants		F_2 plants		χ^2 (1:3)	χ^2 (3:1)
	PHS	PHN	PHS	PHN		
P_1 x P_2	24	0	24	0	-	-
P_2 x P_1	0	53	0	49	-	-
Total	24	53	24	49	2.42	69.08*

* $p < 0.05$; χ^2: Chi-square; ♀: Mother (recipient) plant; ♂: Father (donor) plant; P_1: TVu11953; P_2: Ife Brown; PHN: photoperiod neutral; PHS: photoperiod sensitive.

The presence of photoperiod sensitivity in plant individuals from photoperiod sensitive maternal plants both in the F_1 and F_2 generation cowpea plants showed photoperiod sensitivity to be maternally influenced. This is similar to the reports of Manggoel and Uguru (2011) who showed that flowering time as an indication of the photoperiod was maternally influenced. They stated that the wide gap in days to first flowering between the photoperiod sensitive and photoperiod neutral cowpea accessions can be linked to different factors other than Mendelian inheritances. The maternal inclination with respect to the number of days to flowering in the offspring implies that progenies from crosses with photoperiod sensitive accessions as maternal parents will not flower until a certain critical photoperiod is attained. However, pooled results of observations from F_2 generation plants showed a goodness of fit to expected 3:1 ratio for photoperiod neutral to photoperiod sensitive (χ^2(3:1) = 2.42, $p > 0.05$) (Table 6). This did not corroborate with the work of Sene (1967) who reported that photoperiod sensitivity was controlled by a single gene completely dominant over the photoperiod neutral gene in cowpea. The result from the segregation pattern observed among pooled sampled F_2 plants might be due to the unequal number of plants examined from both maternal lines. However, if the same number of plants were pooled together from maternal lines and examined, the goodness of fit would result in a ratio of 1:1, indicating that the trait was maternally inherited. Earlier works of Ishiyaku et al. (2005) have suggested polygenic control with epistasis gene action while the work of Kongjaimun et al. (2012) reported ten QTLs responsible for flowering time in cowpea.

Segregation of cowpea flower colours

Sangwan and Lodhu (1998) have stated that flower colour is less influenced by environment variations and that they are used as markers in the identification of species or varieties. The observation of purple flowers on hybrid plants from seeds of both parental maternal lines in the F_1 generation shows purple colouration of cowpea flowers to be dominant over white flower colourations. In the F_2 generation, purple flowers showed a dominant segregation pattern over the white-coloured flowers (χ^2(3:1) = 0.11, $p > 0.05$) (Table 7). This result is similar to the works of Cobbinah et al. (2011) who also reported a higher frequency of cowpea plants with the purple flowers than with the white flowers in the F_2 plants generated from a cross between purple-flowered and white-flowered cowpea accessions. Uguru (1995b) observed a partial colour dominance of purple petal colour over white petal colour in a cross of white and purple petal coloured parents. Sangwan and Lodhu (1998) have reported that inheritance of flower colour in cowpea showed a monogenic inheritance with purple flowers dominant over white flowers both in F_2 and backcross populations evaluated in their study.

Table 7. A segregation pattern of flower colours in F_1 and F_2 cowpea generations.

Crosses (♀ + ♂)	F_1 plants		F_2 plants		χ^2 (1:3)	χ^2 (3:1)
	Purple	White	Purple	White		
P_1 x P_2	24	0	24	0	-	-
P_2 x P_1	53	0	32	17	42.46*	2.46
Total	77	0	56	17	104.11*	0.11

* $p < 0.05$; χ^2: Chi-square; ♀: Mother (recipient) plant; ♂: Father (donor) plant P_1: TVu11953; P_2: Ife Brown.

Phenotypic evaluation and heritability of quantitative traits in the F_2 cowpea populations

Genetic variability is the basic information needed for breeders to improve crops by adopting the appropriate method of selection based on the variability that exists in the plant material (Sharma et al., 2017). Phenotypic evaluation of the F_2 plants showed variation to be the highest in leaf petiole length in the F_2 population followed by 100-seed weight and the lowest in seed width. The heritability estimates are important genetic parameters that play a significant role in selection of different cowpea genotypes from a population (Manggoel et al., 2012). Heritability was high for all traits evaluated in the F_2 population except for leaf petiole length which had the lowest heritability of 45% compared to 100-seed weight which had the highest heritability of 96% (Table 8). This is similar to reports of Omoigui et al. (2006) and Inuwa et al. (2012) who also reported similar high heritability for 100-seed weight. However, the high heritability for pod length (H^2 = 75%) observed in this study did not corroborate with the report of Omoigui et al. (2006) who reported a moderate heritability of 43% for pod length in their study. The low heritability observed in leaf petiole length corroborates with the findings of Inuwa et al. (2012). High broad-sense heritability values usually indicate the predominance of additive gene action in the expression of the traits (Manggoel et al., 2012).

Table 8. Quantitative traits evaluated in F_2 cowpea population.

Traits	Parents		F_2 generation				H^2
	TVu11953	Ife Brown	Mean	Min–Max	SD	CV	
TLL	15.43	13.51	11.42	5.40–17.40	2.08	18.25	86
LPL	8.36	11.43	8.06	3.10–13.30	2.18	27.00	45
PDL	7.08	11.05	10.75	5.00–15.80	2.05	19.02	75
PDW	6.00	7.90	7.24	4.88–12.60	0.90	12.45	94
SDL	10.64	7.98	9.25	6.80–11.44	0.98	10.62	89
SDW	7.47	5.77	6.26	4.57–7.65	0.57	9.19	92
SDTK	5.93	4.38	4.78	3.78–5.79	0.48	9.95	88
100SDWT	26.32	15.23	17.46	9.80–27.87	3.79	21.72	96

Min: Minimum; Max: Maximum; SD: Standard deviation; CV: Coefficient of variation (%); H^2: Heritability (%); TLL: Terminal leaflet length (cm); LPL: Leaf petiole length (cm); PDL: Pod length (cm); PDW: Pod width (mm); SDL: Seed length (mm); SDW: Seed width (mm); SDTK: Seed thickness (mm); 100SDWT: 100-seed weight (g).

Correlation between cowpea quantitative traits and *C. maculatus* resistance

Contrasting quantitative traits between TVu11953 and Ife Brown were correlated with *C. maculatus* resistant measures (mean development period and percentage adult emergence) in the F_2 segregating population. Terminal leaf length, seed length, seed weight and seed thickness had a negative correlation with the mean development period (-0.05, -0.04, -0.03, -0.05, respectively). Other quantitative traits showed a positive correlation with the percentage adult emergence of *C. maculatus* insects in the F_2 generation. Terminal leaflet length, leaf petiole length, pod length, pod width and seed thickness showed a negative correlation with the number of eggs laid by *C. maculatus* insects in the study on F_2 generation seeds evaluated (Table 9). Several authors have reported bruchid resistance to be associated with several phenotypic traits in related crop species. These include seed size, seed coat texture, seed thickness and seed colour in mungbean and green gram varieties (Mei et al., 2009; Gupta and Apte, 2016; Soumia et al., 2017). Though both positive and negative associations were observed between the contrasting traits and *C. maculatus* resistance measures in the study, these relationships were weak and not significant. They can therefore not be used in predicting *C. maculatus* tolerance levels in cowpea genotypes.

Table 9. Cowpea quantitative trait correlations with mean development period, percentage adult emergence of insects and the number of eggs laid by *C. maculatus*.

Characters	MDP	PAE	ESD
Terminal leaflet length (cm)	-0.05	0.12	-0.06
Leaf petiole length (cm)	0.13	0.08	-0.02
Pod length (cm)	0.00	0.14	-0.28
Pod width (mm)	0.08	0.32	-0.28
Seed length (mm)	-0.04	0.09	0.10
Seed width (mm)	-0.03	0.08	0.10
Seed thickness (mm)	-0.05	0.23	-0.15
100-seed weight (g)	0.04	0.14	0.02

MDP: Mean insect development period; PAE: Percentage adult emergence; ESD: Number of eggs laid (Oviposition).

The test of independent assortment between *C. maculatus* resistance and some cowpea traits

Genotype resistance when employed as an option to minimise cowpea losses caused by *C. maculatus* during storage is the best alternative to manage *C. maculatus* damage (Tripathy, 2016). The development of resistant cultivars is, however, still very limited, since few high resistance sources have been identified (Singh et al., 1985; Dongre et al., 1996). The segregations of several contrasting traits between the TVu11953 and Ife Brown genotypes were tested for association segregation of *C. maculatus* resistance measured by MDP. All the traits evaluated showed independent segregation assortment with MDP in the F_2 population evaluated (Table 10). Similarly, independent assortment between PAE with these contrasting traits between TVu11953 and Ife Brown was analysed to check for segregation association with *C. maculatus* resistance. The analysis showed that none of the traits evaluated had a significant association with PAE (Table 11).

Table 10. The test of independent assortment of cowpea traits with the bruchid mean development period.

Traits	Phenotype	MDP		χ^2	*p*
		Resistant	Susceptible		
Seed coat colour	Mottled	0	19	2.37	0.34
	Intermediate	2	34		
	Brown	2	15		
Seed shape	Kidney	1	37	1.31	0.34
	Rhomboid	3	31		
Photoperiod sensitivity	PHS	1	24	0.18	0.67
	PHN	3	44		
Flower colour	Pink	3	52	0.01	0.95
	White	1	16		
Seed weight	Large	0	26	2.39	0.29
	Small	4	42		

χ^2: Chi-square; *p*: Probability value; MDP: Mean development period; PHS: Photoperiod sensitive; PHN: Photoperiod neutral.

Table 11. The test of independent assortment of traits with the bruchid percentage adult emergence.

Traits	Phenotype	PAE		χ^2	*p*
		Resistant	Susceptible		
Seed coat colour	Mottled	0	19	4.54	0.10
	Intermediate	2	34		
	Brown	3	14		
Seed shape	Kidney	1	37	2.32	0.18
	Rhomboid	4	30		
Photoperiod sensitivity	PHS	1	24	0.51	0.65
	PHN	4	43		
Flower colour	Pink	4	51	0.04	0.84
	White	1	16		
Seed size	Large	0	26	3.01	0.15
	Small	5	41		

χ^2: Chi-square; *p*: Probability value; PAE: Percentage adult emergence; PHS: Photoperiod sensitive; PHN: Photoperiod neutral.

Conclusion

The identification of discriminating traits between *C. maculatus* resistance and susceptibility in cowpea would be an added tool for easy identification and breeding of *C. maculatus* resistant genotypes. Contrasting morphological traits between *C. maculatus* resistant and susceptible genotypes in this study showed a low correlation and no association with *C. maculatus* resistance. This indicates that

C. maculatus resistance is not solely dependent on seed traits as suggested by some authors for related crops. There is a need therefore to employ other more technical approaches that would better help in *C. maculatus* resistant genotype selection among cowpea germplasm lines.

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MORFO-GENETSKA VARIJABILNOST KOD GENOTIPOVA VIGNE F_2 GENERACIJE POTOMSTVA TOLERANTNIH NA BRUHIDU (*Callosobruchus maculatus*)

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R e z i m e

Callosobruchus maculatus Fab. predstavlja najveću pretnju proizvodnji vigne, smanjujući kvalitet, količinu i tržišnu vrednost zrna. Metoda jeftine i jednostavne identifikacije bila bi dragoceno sredstvo u identifikaciji i oplemenjivanju otpornih genotipova u obimnoj germplazmi vigne. Stoga, svrha ovog istraživanja bila je da se identifikuje i proceni genetika osobina vigne između biljnih genotipova otpornih i osetljivih na *C. maculatus*. Kontrastne kvalitativne i kvantitativne osobine kod otpornih i osetljivih roditelja na *C. maculatus* procenjene su kod 72 biljke vigne F_2 generacije potomstva. Heritabilnost, segregacija i asocijativnost ispitivanih osobina sa performansama genotipova vigne F_2 generacije otpornim na *C. maculatus* su ocenjeni, kako bi se odredile blisko povezane osobine sa otpronošću na *C. maculatus*. Rezultati istraživanja pokazali su visoku heritabilnost za sve kvantitativne osobine vigne, osim dužine peteljke lista. Mendelevsko i ne-Mendelevsko nasleđivanje primećeno je među kvalitativnim osobinama. Međutim, asocijativna procena između osobina vigne i prosečnog perioda razvoja bruhide, procenta pojave odraslih jedinki i sklonosti ovipoziciji bila je slaba ($r <0,5$) i nije bila značajna ($p <0,05$). Ovo ukazuje na to da se otpornost prema *C. maculatus* kod vigne može pripisati faktorima, koji se ne odnose na morfološke varijacije.

Ključne reči: *Callosobruchus*, vigne, varijabilnost, osetljivost, otpornost, morfologija.

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EFFECTS OF PROCESSING METHODS AND LEVELS OF INCLUSION OF *Jatropha curcas* KERNEL MEAL ON PERFORMANCE, ORGAN CHARACTERISTICS, HAEMATOLOGY AND SERUM CHEMISTRY OF FINISHER BROILER CHICKENS

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Abstract: Three hundred 21-day-old broiler chicks were reared using a 3 x 3 factorial model in a completely randomized design with 10 treatment groups having 3 replicates of 10 birds each. The birds were raised on a commercial starter diet at the starter phase before being allotted into dietary groups in a 21-d feeding trial at the finisher phase. The interaction between treatment and varying inclusion levels of processed-fermented *Jatropha curcas* (L) kernel meals (JKM) on the performance of broiler chicks was investigated. *Jatropha curcas* kernels were subjected to three different processing methods, namely: raw defatted fermented meal (RDFM), cooked defatted fermented meal (CDFM) and lye treated defatted fermented meal (LDFM). Each meal was included at varying inclusion levels of 2.5%, 5.0% and 7.5% such that diet 1 (control) contained 0% JKM while diets 2, 3, 4 contained 2.5%, 5.0% and 7.5% RDFM, diets 5, 6, and 7 contained 2.5%, 5.0% and 7.5% CDFM and diets 8, 9, 10 contained 2.5%, 5.0% and 7.5% LDFM. Feeding differently processed-fermented JKM to these broilers did not ($p>0.05$) compromise the feed conversion ratio. The results indicated an improvement ($p<0.05$) in the weight gain of broiler chicks fed CDFM and LDFM at 2.5 and 5.0% inclusion levels respectively. There were significantly ($P<0.05$) elevated levels of alkaline phosphatase and creatinine in their blood serum. The kidney, lungs and proventriculus of birds fed CDFM showed significant differences ($p<0.05$) among the treatments. Therefore, finisher broilers could tolerate up to 5.0% inclusion level of LDFM.

Key words: *Aspergillus niger*, blood, broilers, growth, *Jatropha curcas* kernel meal, organ weight.

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Introduction

Jatropha curcas is an underutilized, oil bearing crop. The oil content of its seed compares well with groundnut kernel, rape seed and soybean seed. The oil is almost all stored in the kernel which has an oil content of around 50–55% (Jongschaap et al., 2007; Ojediran and Emiola, 2012). This oil content has attracted interest in the biofuel industry, while the protein content of the cake is of interest to livestock nutritionists. The seed has been reported to have about 35–50% crude protein (Aslaniet al., 2007) although Ojediran and Emiola (2012) reported a crude protein content of 23.57% in the untreated kernel meal. Nonetheless, the myriad of antinutrients (lectin, saponin, tannin, phytate, trypsin inhibitors and phorbol esters) inherent in the unprocessed *Jatropha curcas* seed or kernel meals pose a risk to humans and livestocks.

Sumiati et al. (2007) reported that feeding *Jatropha curcas* meal at the level of 5% in the diet to the broilers reduced feed consumption and caused 100% mortality at the age of 22 days while Ojediran et al. (2014) reported that feeding raw and locally treated (cooked, toasted, lye-treated and sand-roasted) *Jatropha curcas* kernel meals to broiler chicks resulted in depressed feed intake, weight gain and high mortality ranging from 43.33% to 83.33% within 21 days of the feeding trial.

In previous studies, Belewu and Sam (2010) used *Aspergillus niger* to detoxify *Jatropha curcas* kernel meals with a significant reduction of the anti-nutritional compounds such as phorbolesters, lectins, saponins and phytate. Akande et al. (2012) reported that lye treatment, followed by fermentation produced better results in terms of feed consumption. Ojediran et al. (2016) used a combination of different local methods coupled with fermentation and fed the resultant meals to broiler chicks. This improved average daily feed intake, average daily gain and mortality in birds. The result was attributed to the reduction in phorbol esters during fermentation, but concluded that the birds cannot tolerate the 10.33% inclusion level.

Ojediran and Emiola (2018) were able to establish the tolerable level of inclusion and suggested that broiler chicks could tolerate cooked defatted fermented meal and lye treated defatted fermented meal (up to 2.5% and 5.0% inclusion respectively). Therefore, additional research will be required to investigate the response of broilers to processed-fermented *Jatropha curcas* kernel meal at the finisher phase.

Materials and Methods

Experimental site, birds and management

The feeding trial was conducted at the Poultry Unit of the Teaching and Research Farm, Ladoke Akintola University of Technology, Ogbomoso, Nigeria. Three hundred (300) 21-day-old Marshal strain broiler chicks were used for this study. All the birds were initially fed on commercial broiler feed for the starter phase before being randomly allotted without sexing into ten dietary groups of thirty (30) birds each. Each group was further sub-divided into three replicates of ten (10) birds each. The birds were fed with their respective diets and water was served *ad libitum.* The experimental chicks were raised under intensive care management in a deep litter system for three weeks.

Feeds and feeding/Source of test material

Mature *J. curcas* seeds were sourced locally. The seeds were dehulled to remove the kernel. The kernel was later treated as follows (solid state fermentation was done using *Aspergillus niger*):

i. A portion of the kernel was milled and subjected to oil extraction using a hydraulic press after which it was fermented and was referred to as the raw defatted fermented meal (RDFM).

ii. Another portion of the raw kernel was cooked at 120^0C ± 5^0C for 30 minutes in a cooking pot. The treated kernel was dried, milled, fermented and was referred to as the cooked defatted fermented meal (CDFM).

iii. The lye was prepared by putting wood ash in a muslin cloth, and hot water (100^0C ± 5^0C) was poured on the ash. Then the filtrate (pH 9.5) was used to cook another portion of the kernel at 120^0C ± 5^0C for 30 minutes. The treated kernel was dried, milled, fermented and was referred to as the lye defatted fermented meal (LDFM).

All meals were between 0.5 and 1.0mm mesh size. The preparation and sub-culturing of the fungi and innoculation of the substrates followed the procedure as described by Ojediran et al. (2016). However, the fungi growth was terminated by oven drying at 85°C.

Experimental diets

Ten (10) experimental diets were formulated. The test ingredients (RDFM, CDFM and LDFM) were included at varying levels of 2.5%, 5.0% and 7.5% for each fermented meal while the control (Diet 1) had 0% of JKM. Diets 2, 3, 4, contained 2.5%, 5.0% and 7.5% of RDFM, diets 5, 6, and 7 contained 2.5%, 5.0%

and 7.5% of CDFM and diets 8, 9, 10 contained 2.5%, 5.0% and 7.5% of LDFM respectively. The gross composition of the experimental diets is presented in Table 1.

Table 1. Gross composition of experimental diets for finisher broilers (4–6 weeks).

		RDFM			CDFM			LDFM		
Ingredients%	Control	2.5%	5.0%	7.5%	2.5%	5.0%	7.5%	2.5%	5.0%	7.5%
Maize	465.00	465.00	465.00	465.00	465.00	465.00	440.00	465.00	465.00	465.00
Wheat offal	205.00	205.00	195.00	195.00	205.00	205.00	230.00	205.00	205.00	205.00
SBM	270.00	245.00	220.00	195.00	245.00	220.00	195.00	245.00	220.00	195.00
JCKM	0.00	25.00	50.00	75.00	25.00	50.00	75.00	25.00	50.00	75.00
Fishmeal	20.00	20.00	30.00	30.00	20.00	20.00	20.00	20.00	20.00	20.00
#Fixed ingre	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00
Total	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00
Calculated analysis										
CP (%)	209.20	208.60	213.40	212.80	207.70	206.50	206.50	208.60	207.70	207.30
CF (%)	44.50	43.80	42.40	41.80	44.30	44.30	49.10	44.00	43.70	46.50
ME (kcal/kg)	2766.16	2807.73	2859.22	2900.79	2813.81	2861.46	2870.20	2891.86	2853.02	2896.15

#Fixed ingredients include 1.35% Limestone, 2.00% Dicalcium phosphate, 0.20% Salt, 0.25% *Vitamin premix, 0.15% Methionine, 0.05% Lysine; *Vitamin premix contained the following vitamins and minerals in 1kg of broiler diet: 12500 IU Vit. A; 2500 IU Vit. D_3; 40mg Vit.E; 2mg Vit.K_3; 30mg Vit B_1; 55mg Vit.B_2; 550mg Niacin; 115mg Calcium pantothenate; 50mg Vit B_6 ; 0.25mg Vit B_{12}; 500mg Choline chloride; 10mg Folic acid; 0.08mg Biotin; 120mg Manganese; 1000mg Fe; 80mg Zn; 8.5mg Cu; 1.5mg I; 0.3mg Co; 0.12mg Se and 120mg Antioxidant; SBM = Soyabean meal, JCKM = *Jatropha curcas* kernel meal, CP = Crude protein,CF = Crude fibre, ME = Metabolizable energy, RDFM = Raw defatted fermented meal, TDFM = Toasted defatted fermented meal, CDFM = Cooked defatted fermented meal, LDFM = Lye defatted fermented meal.

Data collection/Growth performance

The average daily feed intake (ADFI), average daily gain (ADG) and total weight gain were monitored and recorded throughout the feeding trial. Feed to gain ratio of the experimental birds was calculated.

Blood chemistry analysis

Three birds per treatment were randomly selected and 5ml of blood was collected into a pair of three sterilized glass bottles/tubes. For haematological examination, blood samples were collected into three sterilized bottles containing ethylene diamine tetra-acetic acid (EDTA), while those for serum biochemical studies were collected into three plain bottles (i.e without anticoagulant). Serum was obtained by centrifugation and serum samples were stored in a deep freezer (at minus 10^0C) until required for analysis.

Blood parameters such as packed cell volume (PCV) and haemoglobin (Hb) were determined using the micro haematocrit method and cyanomethehemoglobin methods respectively as described by Mitruka and Rawnsley (1977). Erythrocyte count (RBC) and leukocyte count (WBC) were determined using the improved Neubauer haemocytometer after the appropriate dilution (Schalm et al., 1975). Differential leukocyte counts were determined by scanning Giemsa's stained slides in the classic manner (Schalm et al., 1975) while mean corpuscular value, mean corpuscular haemoglobin, and mean corpuscular haemoglobin concentration were calculated using the formula described by Ojediran et al. (2015). Cholesterol was determined by spectrophotometric methods. Alanine aminotransaminase (ALT), aspartate aminotransaminase (AST) and alkaline phosphatase (ALP) were determined manually by the spectrophotometric method respectively as described by Schmidt and Schmidt (1963). Total serum protein was determined using the biuret method as described by Reinold (1953) while albumin was determined using the BCG (Bromocresol green) method as described by Peters et al. (1982).

Weight of organs

At the end of the 4^{th} week, all the birds were starved overnight and each bird was randomly selected per replicate, tagged, weighed and slaughtered for carcass analysis. After the birds had been slaughtered, an incision was carefully made around the abdomen with a pen knife to create space through which the visceral organs were brought out. The weights of the kidneys, heart, liver, lungs, gizzard, proventriculus and pancreas were taken. The organs were weighed using the sensitive electronic weighing scale and their respective weights were recorded and expressed as a percentage of live body weight.

Experimental design and statistical analysis

All data generated and estimated were subjected to analysis of variance for a 3 x 3 factorial model in a completely randomized design of the SAS (2000) software package. Significant means were separated using Duncan's multiple range test of the same package.

Results and Discussion

Interaction effects between treatment and inclusion levels on the growth performance of finisher broiler chickens fed graded levels of processed-fermented *Jatropha curcas* kernel meal are presented in Table 2. The final body weight (FBW), average daily feed intake (ADFI) and average daily gain (ADG) were significantly influenced. A linear decrease was observed in birds fed the dietary treatments. At the 5.0% inclusion level, birds fed on the JKM had similar FBW and ADG especially those feed RDFM and LDFM, although those fed CDFM and LDFM had similar (P>0.05) ADFI within the treatments. Birds fed on RDFM and LDFM had FBW and ADG that are comparable to those fed on the control diet up to the 5.0% inclusion level, although birds fed on LDFM were not significantly different (P>0.05) from those fed on control diet at all inclusion levels. No significant difference was observed for feed conversion ratio and mortality. The performance recorded in this study when broilers were fed JKM at the finisher phase was better than that at the starter phase reported by Ojediran and Emiola (2018). This may be attributed to improved gut physiology. Akande et al. (2012) reported that lye treatment, followed by fermentation produced better results in terms of feed consumption and this is similar to the observations in this study. Broilers fed on LDFM had a higher feed intake at the 7.5% inclusion level.

Table 2. Interaction effects of the processed-fermented *Jatropha curcas* kernel meal on growth performance of finisher broiler chickens.

Parameters	Treatments	0%	2.5%	5.0%	7.5%	SEM
Initial B (g/b)	RDFM	511.67	513.33	511.67	511.67	6.87
	CDFM	511.67	485.71	490.95	492.86	4.91
	LDFM	511.67	513.33	513.33	514.33	6.01
	SEM	11.67	11.84	11.10	15.50	
Final B (g/b)	RDFM	1236.11[a]	1126.67[ab]	1116.20[b,x]	1040.19[b]	25.80
	CDFM	1236.11[a]	1201.98[a]	984.76[b,y]	950.56[b]	41.85
	LDFM	1236.11[a]	1199.49[ab]	1174.54[ab,x]	1023.52[b]	33.81
	SEM	51.89	40.85	33.17	33.72	
ADFI	RDFM	111.23[a]	95.17[b,y]	94.03[b]	89.44[b]	2.62
(g/b/d)	CDFM	111.23[a]	104.04[ab,x]	92.47[b]	95.02[b]	2.71
	LDFM	111.23	105.41[x]	107.39	98.59	2.26
	SEM	1.28	1.61	4.81	3.03	
ADG	RDFM	34.50[a]	29.21[b]	28.79[b,x]	25.17[b]	1.17
(g/b/d)	CDFM	34.50[a]	34.11[a]	23.52[b,y]	21.80[b]	1.93
	LDFM	34.50[a]	32.67[ab]	31.49[ab,x]	24.25[b]	1.62
	SEM	2.32	2.02	1.19	1.30	
FCR	RDFM	3.25	3.27	3.27	3.56	0.07
	CDFM	3.25	3.05	3.98	4.51	0.25
	LDFM	3.25	3.34	3.44	4.06	0.15
	SEM	0.21	0.58	0.31	0.29	
Mortality	RDFM	0.00	0.00	0.00	0.00	0.00
	CDFM	0.00	0.00	0.00	4.76	1.19
	LDFM	0.00	0.00	0.00	0.00	0.00
	SEM	0.00	0.00	0.00	1.59	

[abc] Means with different superscripts in the same row are significantly different (P<0.05).[xyz] Means with different superscripts in the same column are significantly different. RDFM: Raw defatted fermented meal, CDFM: Cooked defatted fermented meal, LDFM: Lye defatted fermented meal, ADFI: Average daily feed intake, ADG: Average daily gain, FCR: Feed conversion ratio and SEM: Standard error of the mean.

All the dietary treatments had a lower feed consumption rate when compared to the control. Akande and Odunsi (2012) concluded that it is evident that the higher the inclusion of Castor bean cake, the lower the performance of birds in treated groups. They reported that the 10% inclusion compared favourably with control while the 15% in lye treated group also compared well with control while up to 15% of the thermal and lye treatment could be used in feeding broiler chickens without a deleterious effect. The fermented product may be safely used at the 10% rate of inclusion. The inclusion level significantly influenced the ADG of broiler chickens fed processed-fermented JCKM. Birds fed on CDFM compared favorably with the control at the 2.5% inclusion level while birds fed on LDFM compared favorably with the control at the 5.0% inclusion level, though birds fed on the processed-fermented JCKM were comparable at the 7.5% inclusion. This differed from the report of Sumiati et al. (2009) who showed that feeding on 5% untreated as well as fermented *Jatropha curcas* did not influence the feed consumption of kampong chickens. Sumiati et al. (2009) reported that the supplementation of the enzymes to the diets containing fermented *Jatropha curcas* meal tended to raise final body weight of kampong chicken. The reason for this could be attributed to the microbial phytase supplementation (breaking of the bonds that held nutrients bound or trapped in cell walls and therefore unavailable for microbial degradation) that increased body weight gain, feed intake and feed efficiency in broiler chickens (Singh et al., 2003).

Interaction effects between treatments and inclusion levels of finisher broilers fed graded levels of the *Jatropha curcas* kernel meal on the hematological parameters are presented in Table 3. Birds fed RDFM had their PCV, Hb MCH and MCV significantly different ($p<0.05$) and this is similar to those fed LDFM for WBC, heterophil, eosinophil and basophil.

Birds fed on CDFM diets had significantly different ($p<0.05$) RBCs and lymphocytes while MCH and MCV were significantly different ($p<0.05$) within treatments at the 5% inclusion level. The values obtained for PCV for all the treatment groups were within the normal range of 24.9–45.2% as reported by Mitruka and Rawnsley (1977), but it differed from the range of 22–26% reported by Ameenet al. (2007). Hemoglobin values did not agree with the findings of Akande and Odunsi (2012), who fed broiler chicks with detoxified castor kernel cake, and the values of hemoglobin tended to be decreasing across the dietary treatments. The values of PVC and RBC were within the ranges of 30–35% and 2.88–4.12 x 10^6 mm^3 as reported by Swenson (1970) and Campbell et al. (2003). Ologhobo et al. (1986) observed that an increase in WBC count above normal is an indication of the presence of exogenous substances and foreign bodies in the body.

The observation on lymphocyte agreed with the findings of Belewu et al. (2011) who fed goats on a cocktail of fungi treated *Jatropha curcas* kernel cake, and observed a decrease in the lymphocyte values when compared with the control. Lymphocytes are known to play key roles in the immune defense system of both humans and animals. Adeyemo and Longe (2007) observed that graded levels of cottonseed cake fed to broilers from one-day-old to 8 weeks of age did not affect the monocyte and basophil counts. Akande and Odunsi (2012) who fed broiler chicks with detoxified castor kernel cake, observed an increase in eosinophil values compared to the control. Increased eosinophil indicated response to foreign materials. Zomrawi et al. (2012) reported that ginger root powder (*Zingiber officinale*) supplementation had no influence on platelet count and MCHC broiler chicks while the findings of Nworgu et al.(2013) who fed basil leaf (*Ocimum gratissimum*) supplement to growing pullets reported decreased MCV values compared to the control.

Table 3. Interaction effects on haematological parameters of finisher broiler chickens fed fermented *Jatropha curcas* kernel meals.

Parameters	Treatment	0%	2.5%	5.0%	7.5%	SEM
PCV(%)	RDFM	28.67^{ab}	32.33^{a}	32.00^{a}	27.33^{b}	1.57
	CDFM	28.67	29.67	30.00	30.33	1.64
	LDFM	28.67	30.33	27.67	28.67	1.6
	SEM	1.45	1.00	1.51	1.73	
Hb(g/dL)	RDFM	9.57^{ab}	10.80^{a}	10.67^{a}	9.10^{b}	0.51
	CDFM	9.57	9.90	9.97	10.13	0.54
	LDFM	9.57	10.10	9.13	9.57	0.35
	SEM	0.47	0.33	0.47	0.58	
RBC	RDFM	3.18^{b}	3.51^{a}	3.54^{a}	3..44^{ab}	0.08
($\times 10^3$µl)	CDFM	3.18^{b}	3.42^{ab}	3.51^{a}	3.49^{ab}	0.10
	LDFM	3.18	3.30	3.53	3.31	0.08
	SEM	0.02	0.05	0.12	0.15	
WBC	RDFM	12.60	15.28	13.23	13.83	2.56
($\times 10^6$ µl)	CDFM	12.60	15.62	15.47	16.08	1.90
	LDFM	12.60^{b}	16.88^{ab}	15.00^{ab}	20.47^{b}	2.52
	SEM	2.31	2.15	2.74	2.10	
Lymphocyte	RDFM	77.67	69.33	67.33	67.67	2.49
($\times 10^6$ µl)	CDFM	77.67^{a}	66.67^{b}	66.67^{b}	65.33^{b}	2.84
	LDFM	77.67^{a}	62.67^{b}	68.33^{ab}	72.33^{ab}	3.54
	SEM	1.45	2.73	3.90	3.74	
Heterophil	RDFM	17.33	26.67	27.33	43.44	3.56
($\times 10^6$ µl)	CDFM	17.33	25.33	30.00	24.33	2.32
	LDFM	17.33^{b}	33.00^{a}	25.67^{ab}	18.00^{b}	8.22
	SEM	1.76	4.24	3.83	8.96	
Eosinophil	RDFM	3.33	2.00	2.33	2.67	0.55
($\times 10^6$ µl)	CDFM	3.33	1.33	2.33	2.33	0.39
	LDFM	3.33^{ab}	2.00^{b}	3.33^{ab}	3.67^{a}	0.71
	SEM	0.33	0.69	0.56	0.63	
Basophil	RDFM	0.33	0.00	0.33^{y}	0.33	0.17
($\times 10^6$ µl)	CDFM	0.33	0.67	0.00^{y}	0.00	0.17
	LDFM	0.33^{ab}	0.00^{b}	1.00^{a,x}	0.33^{ab}	0.25
	SEM	0.33	0.11	0.11	0.22	
Platelet	RDFM	13.07	13.80	16.33	14.17	2.00
($\times 10^4$)	CDFM	13.07	14.73	17.57	17.17	2.63
	LDFM	13.07	16.70	14.40	16.60	1.67
	SEM	1.91	2.61	1.76	2.12	

Table 3.Continued.

Parameters	Treatment	0%	2.5%	5.0%	7.5%	SEM
MCH(fl)	RDFM	30.09^{ab}	30.79^{a}	$30.12^{ab,x}$	26.46^{b}	1.00
	CDFM	30.09	28.97	28.32^{xy}	28.92	1.17
	LDFM	30.09	30.56	25.87^{y}	29.01	1.00
	SEM	1.25	1.12	0.68	1.16	
MCHC(%)	RDFM	33.38	33.40	33.33	33.29	0.08
	CDFM	33.38	33.37	33.28	33.36	0.10
	LDFM	33.38	33.36	33.03	33.37	0.04
	SEM	0.08	0.05	0.12	0.04	
MCV(pg)	RDFM	90.18^{ab}	92.18^{a}	$90.38^{ab,x}$	79.47^{b}	3.10
	CDFM	90.18	86.80	85.23^{xy}	86.58	3.49
	LDFM	90.18	91.78	78.33^{y}	86.92	3.03
	SEM	3.91	3.30	2.18	3.44	

[abc] Means with different superscripts in the same row are significantly different (P<0.05).[xyz] Means with different superscripts in the same column are significantly different. MCV – Mean corpuscular volume, MCH – Mean corpuscular haemoglobin, MCHC – Mean corpuscular haemoglobin concentration.

Table 4 shows the interaction effects between the treatments and inclusion levels of JKM on serum chemistry of finisher broiler chickens. Total protein and globulin were not significantly (P.0.05) different in RDFM and CDFM at all inclusion levels. However, there was a significant (p<0.05) difference in LDFM between inclusion levels. Alkaline phosphatase was highest at the 7.5% inclusion level for RDFM within treatments. There was no significant (p>0.05) difference in inclusion levels of RDFM. Creatinine was affected along the inclusion levels and within treatments (2.50%–7.50%). The cholesterol level in birds fed RDFM was significantly affected (p<0.05) while those fed CDFM and LDFM were significantly influenced (p<0.05) for triglycerides. Observations on total protein, ALP and AST agreed with the findings of Ojo et al. (2013) who fed finisher broilers with graded levels of raw *Jatropha curcas* based diets. The increase in ALP observed gave an indication that the hepatic capacity of the liver was grossly affected by *Jatropha curcas* (Kaneko, 1989). Aluwong et al. (2013) observed a decrease in ALT activities when broiler chicks were fed different levels of supplemental yeast, while Ojediran et al. (2015) reported that an increased AST, ALT and ALP values might be attributed to liver damage. The globulin values of RDFM and CDFM were not significantly different (P>0.05) from each other, signifying a similar ability to fight against disease. This result agreed with the work of Akinmutimi et al. (2002) who reported a significant decrease in serum globulin of starter broiler chicks fed differently processed sword bean meals. The higher the value of serum creatinine, the lower the protein quality of the test ingredient. This implies the nutritional inferiority of the protein quality of the diets (Aletor et al., 1992). Ojo et al. (2013) have reported that a significant elevation of creatinine and urea is a pointer to renal dysfunction in chickens given *Jatropha curcas.*

Table 4. Interaction effects of the treatment and graded levels of processed-fermented *Jatropha curcas* kernel meals on serum chemistry of finisher broiler chickens.

Parameter	Treatment	0%	2.5%	5.0%	7.5%	SEM
Total protein (g/dl)	RDFM	3.36	3.42[x]	2.99	4.39	0.60
	CDFM	3.36	3.16[xy]	3.19	3.06	0.23
	LDFM	3.36[a]	1.86[b,y]	3.06[ab]	2.92[ab]	0.50
	SEM	0.24	0.54	0.21	0.77	
Albumin (g/dl)	RDFM	1.56	1.75	1.56	1.56	0.13
	CDFM	1.56	1.58	1.60	1.35	0.14
	LDFM	1.56	1.41	1.53	1.61	0.26
	SEM	0.14	0.20	0.13	0.23	
Globulin (g/dl)	RDFM	1.80	1.68[x]	1.43	2.83	0.47
	CDFM	1.80	1.58[x]	1.59	1.72	0.09
	LDFM	1.80[a]	1.22[b,y]	1.55[ab]	1.31[b]	0.24
	SEM	0.10	0.34	0.08	0.54	
ALP (U.I/I)	RDFM	346.97	362.36	394.72	483.29[x]	60.65
	CDFM	346.97[d]	400.19[c]	493.34[a]	469.96[b,xy]	7.03
	LDFM	346.97[b]	442.26[a]	417.25[a]	431.19[a,y]	27.07
	SEM	2.17	52.34	53.44	18.36	
AST (U.I/I)	RDFM	195.71	195.10	198.24	185.16	13.49
	CDFM	195.71	175.73	174.69	185.33	17.97
	LDFM	195.71	195.28	193.01	196.33	6.79
	SEM	8.66	22.15	11.14	9.05	
ALT (U.I/I)	RDFM	6.35	5.49	5.49	6.24[y]	2.61
	CDFM	6.35	4.53	4.04	5.71[y]	2.35
	LDFM	6.35	8.11	7.84	11.81[x]	2.97
	SEM	4.29	1.82	3.16	1.30	
Creatinine (mg/d)	RDFM	0.60[b]	0.73[a,xy]	0.70[ab,y]	0.74[a,y]	0.06
	CDFM	0.60[c]	0.69[b,y]	0.70[b,y]	0.79[a,xy]	0.04
	LDFM	0.60[b]	0.84[a,x]	0.94[a,x]	1.02[a,x]	0.09
	SEM	0.04	0.06	0.06	0.10	
Cholesterol (mg/d)	RDFM	121.11[ab]	146.48[a]	102.65[b]	112.80[ab]	18.89
	CDFM	121.11	117.18	144.17	123.88	21.56
	LDFM	121.11	140.02	128.26	122.26	17.64
	SEM	13.90	18.27	24.07	21.20	
Triglyceride (U.I/I)	RDFM	76.34	54.11	53.04	64.20	24.46
	CDFM	76.34[a]	44.16[b]	47.83[b]	44.44[b]	6.78
	LDFM	76.34[ab]	38.17[b]	87.60[a]	57.65[ab]	20.80
	SEM	11.69	9.54	20.17	27.99	
ACP (U.I/I)	RDFM	6.19	5.34	3.94	3.94	2.17
	CDFM	6.19	5.91	5.06	4.78	1.80
	LDFM	6.19	6.75	5.06	5.34	1.99
	SEM	4.16	1.78	0.71	1.30	

[a,b,c] Means along the same row with different superscripts differ significantly ($p<0.05$). [x,y,z] Means along the same column with different superscripts differ significantly ($p<0.05$).AST – Aspartate aminotransferase, ALT – Alanine aminotransferase, ALP – Alakaline phosphatase, TRY – Triglyceride and ACP – Acid phosphatase.

Creatinine is a breakdown product of creatine. It is usually produced at a fairly constant rate by the body and filtered out of the blood by the kidneys. If the filtering capacity of the kidney is deficient, the blood creatinine level rises (Nwanjo et al., 2005). Ojo et al. (2013) and Ojediran et al. (2015) reported that residual anti-nutrients in *Jatropha curcas* can cause damage to the kidney thereby distorting renal function.

Results of treatment and inclusion effects of processed-fermented *Jatropha curcas* kernel meals on organ parameters of finisher broiler chickens are presented in Table 5. Birds fed CDFM had a significantly influenced ($p<0.05$) kidney, lungs and proventriculus weights. An increase in weight was observed as the level of inclusion increased. Rahma et al. (2013) showed there were no significant differences in liver weights between rats fed casein diet and those fed detoxified *Jatropha* seed flour diet. Similar observations were made in the case of detoxified castor proteins (Puttaraj et al., 1994). However, high kidney weights in rats fed with field bean and navy bean diets have been attributed to low availability of essential amino acids (Ramamani, 1976).

Table 5. Treatment and inclusion effects of processed-fermented *Jatropha curcas* kernel meals on organ parameters of finisher broiler chickens (% live weight).

Parameters	Treatments	0%	2.5%	5.0%	7.5%	SEM
Liver	RDFM	4.02	4.13	4.06	4.92	0.19
	CDFM	4.02	3.51	4.16	4.08	0.14
	LDFM	4.02	3.83	4.67	4.67	0.16
	SEM	0.09	0.22	0.16	0.20	
Kidney	RCDFM	1.25	1.13	1.23	1.39	0.06
	CDFM	1.25^{ab}	1.13^{b}	1.36^{a}	1.38^{a}	0.04
	LDFM	1.25	0.97	1.20	1.48	0.07
	SEM	0.03	0.06	0.04	0.07	
Lungs	RDFM	0.84	0.90	0.98	0.97	0.06
	CDFM	0.84^{b}	0.86^{b}	1.05^{ab}	1.17^{a}	0.05
	LDFM	0.84	0.75	1.10	1.09	0.06
	SEM	0.04	0.07	0.04	0.06	
Heart	RCDFM	0.66	0.69	0.69	0.73	0.04
	CDFM	0.66	0.71	0.73	0.76	0.03
	LDFM	0.66	0.65	0.63	0.77	0.02
	SEM	0.02	0.04	0.03	0.04	
Gizzard	RDFM	6.68	6.96	6.16	5.99	0.29
	CDFM	6.68	5.35	6.16	6.84	0.33
	LDFM	6.68	5.83	7.27	6.88	0.26
	SEM	0.08	0.44	0.27	0.44	
Pancrease	RDFM	0.005	0.005	0.004^{xy}	0.005	0.0003
	CDFM	0.005	0.004	0.003^{y}	0.005	0.0004
	LDFM	0.005	0.003	0.005^{x}	0.005	0.0004
	SEM	0.0001	0.0005	0.0003	0.0004	

Table 5.Continued.

Parameters	Treatments	0%	2.5%	5.0%	7.5%	SEM
Proventiculus	RDFM	0.10	0.97	1.24	1.03	0.07
	CDFM	0.10^{ab}	0.80^{b}	0.89^{b}	1.24^{a}	0.06
	LDFM	0.10	0.79	1.05	1.05	0.06
	SEM	0.02	0.06	0.08	0.09	
Spleen	RDFM	0.28	0.08	0.21	0.22	0.03
	CDFM	0.28	0.21	0.21	0.26	0.02
	LDFM	0.28	0.10	0.13	0.18	0.04
	SEM	0.03	0.03	0.03	0.03	

^{a,b,c} Means along the same row with different superscripts differ significantly (p<0.05). ^{x,y,z} Means along the same column with different superscripts differ significantly (p<0.05). RDFM: Raw defatted fermented meal, CDFM: Cooked defatted fermented meal, LDFM: Lye defatted fermented meal.

Conclusion

This study reveals that finisher broilers could consume up to the 2.5% inclusion level of RDFM and CDFM but up to the 5.0% inclusion level of LDFM comparable with those fed the control diet for final body weight. Nevertheless, feeding JKM to these broilers does not compromise the feed conversion ratio. Observations on the mortality showed that the birds could tolerate all dietary treatments at up to the 5% inclusion level and as much as the 7.5% inclusion level for RDFM and LDFM respectively. The effects of the dietary inclusion levels showed that ALP and CRT increased as the inclusion levels of the test ingredient increased, signifying a compromised kidney integrity attributable to the effect of residual anti-nutrients in JKM.

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UTICAJI METODA PRERADE I NIVOA UKLJUČIVANJA SAČME ZRNA BILJKE *Jatropha curcas* NA PERFORMANSE, OSOBINE ORGANA, HEMATOLOŠKE I BIOHEMIJSKE PARAMETRE BROJLERA U ZAVRŠNOM TOVU

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R e z i m e

Tri stotine 21-dnevnih brojlerskih pilića uzgajano je korišćenjem faktorijalnog modela 3 x 3 po potpuno slučajnom planu sa 10 grupa tretmana koje su imale 3 ponavljanja od po 10 pilića. Pilići su uzgajani korišćenjem komercijalne starter smeše u početnoj fazi, pre nego što su raspoređeni u grupe sa različitim obrocima u 21-dnevnom hranidbenom ogledu u završnoj fazi tova. Ispitivana je interakcija između tretmana i različitih nivoa uključivanja prerađene-fermentisane sačme zrna biljke *Jatropha curcas* (L) (engl. *Jatropha curcas* (L) *kernel meal* – JKM) na performanse brojlera. Zrna biljke *Jatropha curcas* bila su prerađena uz pomoć tri različita metoda: sirova obezmašćena fermentisana sačma (engl. *raw defatted fermented meal* – RDFM), kuvana obezmašćena fermentisana sačma (engl. *cooked defatted fermented meal* – CDFM) i obezmašćena fermentisana sačna tretirana ceđem (engl. *lye treated defatted fermented meal* – LDFM). Nivoi uključivanja sačmi su iznosili 2,5%, 5,0% i 7,5% tako da je obrok 1 (kontrola) sadržao 0% JKM, dok su obroci 2, 3, 4 sadržali 2,5%, 5,0% i 7,5% RDFM, obroci 5 6, i 7 sadržali su 2,5%, 5,0% i 7,5% CDFM i obroci 8, 9, 10 su sadržali 2,5%, 5,0% i 7,5% LDFM. Ishrana brojlera sa različito prerađenim i fermentisanim JKM ($p>0.05$) nije imala negativan efekat na konverziju hrane. Rezultati su ukazali na poboljšanje ($p<0,05$) u prirastu brojlera koji su hranjeni CDFM-om i LDFM-om na nivoima uključivanja od 2,5 odnosno 5,0%. U njihovom krvnom serumu bilo je značajno ($p<0,05$) povišenih nivoa alkalne fosfataze i kreatinina. Bubrezi, pluća i žlezdani želudac pilića hranjenih CDFM-om pokazali su značajne razlike ($p<0,05$) među tretmanima. Prema tome, brojleri u završnom tovu mogu da tolerišu nivo uključivanja LDFM do 5,0%.

Ključne reči: *Aspergillus niger*, krv, brojleri, rast, sačma zrna biljke *Jatropha curcas*, masa organa.

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ECONOMIC JUSTIFICATION OF HONEY PRODUCTION IN SERBIA

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Abstract: Although beekeeping in Serbia has a long tradition, the interest of farmers for this branch of agricultural production depends on the expected economic benefits. Assessing the economic justification of beekeeping is based on the analysis of the revenues from honey production, as the main and often the only beekeeping product, and the expenses generated in production. The aim of the paper is to compare revenues and expenses in the production of honey and to determine the threshold of profitability. The calculation of the revenues and the expenses was made on the basis of data obtained from the survey of beekeepers and from the available secondary sources. The analysis showed that the profitability threshold was achieved with 68 colonies, or with production volume of 1,450 kg of honey. The values of the indicators of economic efficiency, productivity and profitability indicate that beekeeping was economically justified on farms with 100 and 200 colonies.

Key words: beekeeping, honey production, revenues, expenses, economic indicators.

Introduction

Beekeeping is one of the most important branches of Serbian agriculture, especially in the last few decades. The main product of beekeeping is honey, whereas the production of other products is low. Such a structure of bee products is the result of the fact that other products in beekeeping are labour-intensive and require frequent visits to the apiary. This can be achieved on the professional beekeeping farms, focused exclusively on this production, but such producers are in the minority, while more numerous are beekeepers with a smaller number of colonies.

The specialization in production defines not only the structure of assortment of final products, but also the revenues and expenses generated in production, which is reflected in the financial effects. The number of colonies determines the

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total volume of production of honey and other bee products, as well as the economic justification of beekeeping. Producers with a small number of colonies are more likely to practice stationary beekeeping and have less need for additional workers, which results in low production costs (Marinković and Nedić, 2010), and particularly in a small share of labour costs in the structure of total expenses. In addition, these farms generate lower incomes as a result of a smaller volume of honey production. Beekeepers with a large number of colonies have, as expected, higher expenses as a result of larger capacities and different production models that include mobile beekeeping, while labour costs represent the single most important cost item in the total production costs.

The financial success of the production of honey and other bee products depends on the differences in the production technology and structure of revenues and expenses. The aim of this paper is to examine the economic justification of honey production. In accordance with the aim of the research, three specific aims have been defined. The first specific aim is to realistically determine revenues and expenses in mobile beekeeping and to form the basis for calculating selected economic indicators. The second specific aim involves calculating gross margin, economic efficiency, profitability and productivity of labour, as indicators of the justification of honey production. The third specific aim is to determine the number of colonies that guarantees the covering of all costs and beyond which beekeepers can make a profit.

The beekeepers were divided into four categories (with 30, 50, 100 and 200 colonies) and total revenues and expenses were calculated for each group. Based on the obtained data, financial result, threshold of profitability and indicators of economic efficiency, profitability and productivity of production were calculated.

Worldwide, there are several researches focused on the same or similar topic. Vural and Karaman (2010) analysed economic aspects of beekeeping in Turkey within the three sub-groups of producers with 50, 51–100 and more than 101 beehives. Estimations were primarily based on the type of the beehives in use (conventional or technologically modernised). In addition, several estimations of profitability of honey production were done in Nigeria (Okpokiri et al., 2015), Ethiopia (Tarekegn et al., 2017), Iran (Vaziritabar and Esmaeilzade, 2016), and Canada (Laate, 2017).

Materials and Methods

The data used in analysis were collected from three sources. First, the data on the implemented technology and model of production in beekeeping were obtained from a survey conducted on a sample of 98 beekeepers from three regions of the Republic of Serbia (the Belgrade region, the region of southern and eastern Serbia and the region of Šumadija and western Serbia). The survey was conducted in 2017 and the face-to-face method was applied. The second group of data, which was collected on the market, includes prices of the input used in beekeeping and the final product. The third group of data was collected through the interviews with selected producers and based on good beekeeping practices, such as expected consumption, engaged labour force, and quantities of inputs.

Using collected data, the calculation of revenues and expenses of beekeeping by groups of producers was made and several economic indicators of beekeeping were presented. These indicators comprised financial result, gross margin, profitability threshold, and indicators of economic efficiency, profitability and productivity.

The financial result is defined as a difference between total incomes and total expenses, and represents the basic indicator of economic success.

Gross margin is an indicator that is increasingly used in business analysis of farms (Pejanović, 2009). It is calculated as the difference in production value and variable costs, where production value is obtained as the product of selling price and volume of production. When the fixed costs are deducted from the gross margin, the achieved profit is obtained. Since there are several ways of calculating gross margin (Ivanović et al., 2018), it is important to emphasise that, in this paper, subsidies were not included in total revenues when calculating gross margin.

Economic efficiency shows total amount of output that can be obtained on the basis of total investments over a certain period of time. It is calculated as the ratio between total revenues and total costs.

Profitability is an indicator of business success that measures the ability of an enterprise to achieve the best (financial) result with resources invested. While profitability can be calculated in several ways, in this paper it was obtained as the ratio between the financial result and total revenues.

Productivity of labour is equal to the ratio between produced outputs and the amount of labour invested. It also shows the amount of revenue generated per one working hour invested in production. The total numbers of working hours in this analysis were calculated as the sum of hours of permanent workers (beekeepers) and seasonal workers (hired for extracting the honey and moving the beehives). Productivity was calculated as the ratio between the financial result and the total number of working hours.

In addition to these indicators, the profitability threshold was determined as the volume of production that covered total costs, or as the point at which a farm began to make a positive financial result.

Results and Discussion

The number of beehives in Serbia has been continuously increasing since 2007, from 434 to 849 thousand in 2017. According to the results of the 2012 Census of Agriculture in the Republic of Serbia, there are 31,287 beekeeping farms, or 4.95% of the total number of farms. Most of these farms are located in the regions of Šumadija and western Serbia (48%) and southern and eastern Serbia (37%). Beekeepers in Serbia are represented by more than 230 associations.

Natural factors and the quality of bee pasture have a great influence on the production of honey. The maximum production of the most important bee product in the same period was recorded in 2015 (over 12 thousand tons), while in 2017 more than seven thousand tons were produced, which is slightly below the average in the last decade. The increased number of beehives is partly the result of support to beekeepers by the Ministry of Agriculture and local governments, as well as a good organisation of beekeepers (MAFWM, 2018). One of the important reasons for the increased interest and occupation in beekeeping is the appearance of export-oriented companies involved in purchase, processing and distribution of honey, which individually have a large market share in Serbia and guarantee to producers the access to market.

A significant part of the total production of honey (about 28%) in Serbia is produced by professional beekeepers with more than 100 beehives (Marinković and Nedić, 2010), but the fragmentation of production (characteristic for the whole Serbian agriculture) is also present in beekeeping, which means that great quantities of honey are produced by beekeepers with smaller capacities.

Honey is an important export product. The average export of honey from Sebia in the period 2012–2017 was 2,477 tons, in the value of 10,844 thousand US dollars. The most important export area is the EU that absorbs 67.7% of exports, while 18% of the exported quantities of honey were placed on the CEFTA market.

In order to examine the economic justification of beekeeping and to determine the profitability threshold, it was necessary to adopt certain assumptions. The first assumption in the analysis was that beekeepers practice conventional honey production, and all producers practice mobile beekeeping. The beekeeping farms were divided into four groups according to the number of bee colonies, with 30, 50, 100 and 200 colonies. The minimum number was defined according to the number of beehives necessary to obtain the right to subsidies in production. This classification is in accordance with previous research at the national level, related to the number of beehives and the distinction between hobby and professional beekeepers. Hobby beekeepers have 20 hives, advanced hobby beekeepers operate with 50 hives, semi-professional beekeepers have 100 hives, and professional beekeepers run a business with more than 150 hives (Zarić et al., 2013).

Revenues and expenses in the production of honey

The total revenues include revenues from sales of honey and wax and subsidies per hive. Revenues from the sales of honey are generated as a result of the number of hives, honey yield per hive and market prices. According to the research results, the average yield per beehive in the whole sample was 22.2 kg, which is consistent with the previous studies where the average honey yield per beehive in Serbia was 21.6 kg (Panchev et al., 2014), or ranging from 11 to 23 kg (Marinković and Nedić, 2010). There were oscillations per groups of beekeepers, and the highest yield per beehive of 24.0 kg was recorded on beekeeper farms with 200 colonies.

Beekeepers in Serbia sell honey to processors or directly to consumers at green markets, fairs or on the “farm gate” (Pihler et al., 2017). The research results indicate that part of the produced honey was not sold on market, but it was retained on farms for natural consumption, gifts and promotion, and investment in production during the year, in order to reduce production costs. The quantity of produced honey kept on farms varied depending on the production volume and the number of colonies. Beekeepers in the first group (with 30 colonies) kept one fifth of production for their own needs, while the remaining 80% were sold either on the “farm gate” or on the local market, where honey was sold at retail prices. Beekeepers with 50 colonies also retained a fifth of total honey production, 55% sold in retail, and one quarter was delivered to big buyers. Beekeepers with 100 colonies had the following structure: 10% of the total quantities were retained, 20% sold in retail and 70% sold to big buyers. Finally, beekeepers with 200 colonies retained 10% of production and the same percent sold in retail, and most (80%) handed over to big buyers. Total revenues from the sale of honey were made (Table 1) based on the answers of surveyed beekeepers. The structure of the beekeepers’ revenues confirms that honey was the most important product of this branch, given that revenues from sale of honey accounted for about 90% of total revenues.

In addition to revenues from sale of products, beekeepers also have the right to subsidies. The incentives in conventional production of honey in 2017 were paid to the following subjects: legal entities, entrepreneurs and physical persons – owners of commercial agricultural farms. These legal persons, in addition to the conditions prescribed by the law regulating incentives in agriculture and rural development, were supposed to have at least twenty beehives (Official Gazette of the Republic of Serbia, No. 14/2016). The amount of these incentives was 720 RSD per beehive (Official Gazette of the Republic of Serbia, No. 18/2018). Unlike in previous years, when all beekeepers with at least 20 beehives had the right to subsidies, in 2018 subsidies per beehive were paid for at least 30 and up to 200 beehives (Official Gazette of the Republic of Serbia, No. 20/2018). The worst damage caused by changes in conditions for gaining the right to subsidies was made to professional beekeepers having more than 200 beehives. The analysis showed that between 5.4% and 8.4% of total revenues came from subsidies, and the increase in the number of beehives caused the growth of the share of subsidies in total revenues (Table 1).

The effects of subsidies depended on the available capacity on beekeeping farms. The share of subsidies in the revenue structure of beekeepers with fewer beehives was relatively modest, so the effects of these investments were limited. An increased number of beehives resulted in a higher participation of subsidies in the structure of total revenues, which indicates their importance and connection to the overall financial result. Previous research confirms these conclusions. Namely, Nikolić et al. (2018) found that subsidies have a statistically significant influence on the net profits of farms engaged in livestock production. Therefore, the reduction of subsidies has a negative impact on the amount and structure of revenues, and the overall financial result of beekeeping farms, which points to the need for consistency in the application of agricultural policy measures.

Table 1. Total revenues from beekeeping by categories of beekeeping farms.

Type of revenues		Number of colonies			
		30	50	100	200
Value of honey	RSD	372,960	493,095	759,808	1,534,080
	Participation (%)	93.1	91.5	89.3	89.1
Value of wax	RSD	5,995	9,585	19,080	43,200
	Participation (%)	1.5	1.8	2.2	2.5
Revenues from sales of products	RSD	378,954	502,680	778,888	1,577,280
	Participation (%)	94.6	93.3	91.5	91.6
Subsidies in honey production	RSD	21,600	36,000	72,000	144,000
	Participation (%)	5.4	6.7	8.5	8.4
Total revenues (RSD)		400,554	538,680	850,888	1,721,280

Source: Authors' calculation.

Changes in the conditions for gaining the right to incentives in agriculture are a serious limitation in production planning. The beekeepers in Serbia are relatively well-connected by the national organisation called Beekeeping Association of Serbia (SPOS). According to data presented on the website of this organisation, the correction of the conditions regulating the right to incentives can be expected in 2019. The lower level should be re-defined to be 20, while the maximum number of beehives should be one thousand. This is an example how lobbying of nationally representative organisations can be the basis for long-term production planning and consistency in supporting farmers, including beekeepers.

Expenses in conventional beekeeping can be divided into fixed and variable costs. Fixed costs have the same amount regardless of the intensity of capacity utilisation or the changes in production volume. Variable costs vary with the change in production volume and include costs of feeding bees, inputs per product unit, veterinary services, engagement of seasonal labour, fuel costs, lubricants and machinery maintenance, and other variable costs (Ivanović et al., 2018).

The fixed costs include depreciation, the gross wage of beekeepers, or the permanent labour costs, and other fixed costs. Depreciation includes depreciation of equipment, beehives and vehicles (only to the extent used for beekeeping purposes). Investments in capital assets in beekeeping are high, but the useful life is relatively long and implemented rates of depreciation are low (Knaus and Milotić, 2001). The starting assumption in this analysis, when calculating the depreciation costs, is that the value of beekeeping equipment increases with the number of beehives, from 250 to 1,600 euros. The estimated useful life of the capital assets in the calculation is 12 years, and the linear depreciation rate is applied. Depreciation costs increased linearly according to the number of beehives, being the lowest with 7.1% in the case of beekeepers with 30 beehives and the highest with 14.5% in the case of beekeepers with 200 beehives. This is consistent with previous studies (Marinković and Nedić, 2010), although they can exceed 18%, depending on the available equipment (Yildirim and Agar, 2008).

Other fixed costs are those that do not fluctuate with changes in the production level. They include costs related to the sale of products, or the lease of stalls (if other marketing channels, in addition to farm gate sale, are used); membership fees in associations; and analysis of honey quality twice per year, which should be implemented regardless of the marketing channel (Figure 1).

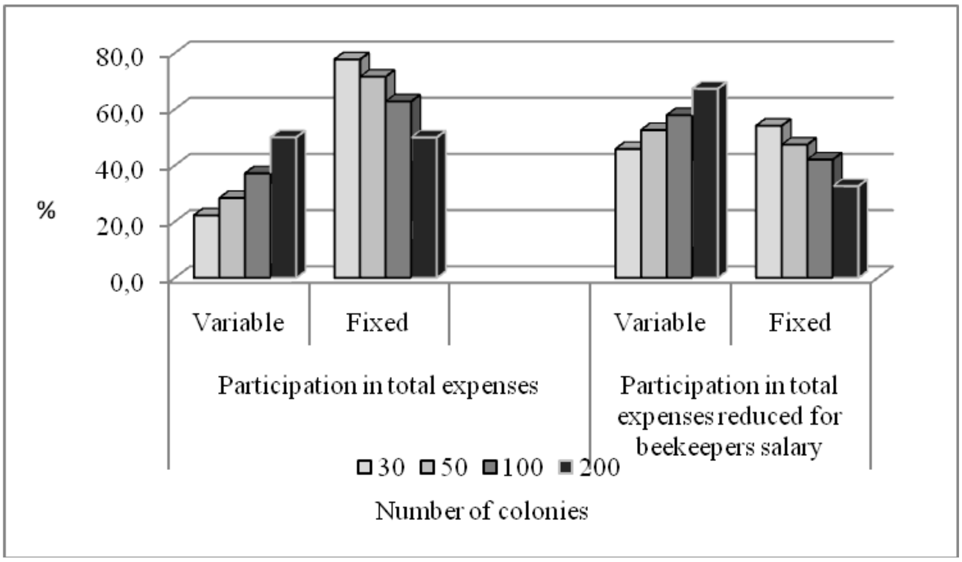

Figure 1. The share of fixed and variable costs in total revenues and revenues reduced for the salary of producers by categories of beekeeping farms.
Source: Authors' calculation.

A particularly important item in the analysis of economic justification of honey production is the costs of permanent labour. Some authors state that labour costs, depending on farm organisation, can be considered as fixed or variable

(Jeločnik et al., 2011). In this analysis, the fixed costs included the ones of engaging permanent workers (beekeepers), while the costs of seasonal workers were classified as variable costs, according to the division of costs in calculating the gross margin (Ivanović et al., 2018).

In addition to the dilemmas regarding the classification of labour costs as fixed or variable, there are also different approaches in the literature related to what items should be included in labour costs. Some authors do not include labour costs in beekeeping calculations, assuming that all the work in the apiary is performed by members of a household (Knaus and Milotić, 2001). The second approach implies that only compulsory contributions to the pension fund are included in the costs of permanent labour (Gugić et al., 2010), which means that the profit generated in the production represents the beekeeper’s income.

In order to estimate revenues and expenses and calculate economic indicators at the real level, the costs of permanent labour presented in the calculation in this paper included a regular contribution for the compulsory pension fund and beekeepers’ salaries. In the calculation, it was assumed that farmers allocate funds for their own salaries on the level of minimum wage in Republic of Serbia. These expenses significantly increased total costs. This relates especially to beekeepers’ salaries which independently made more than a half (51.5%) of the total costs in the group of beekeepers with 30 colonies, and 24.7% of the total costs in the group of beekeepers with 200 colonies. However, this is consistent with other studies (Yildirim and Agar, 2008; Marinković and Nedić, 2010). This approach implies that the profit remaining after the payment of all variable and fixed costs represents the net profit of beekeepers.

The variable costs included the costs of purchasing inputs for production, engagement of a veterinarian, maintenance and moving beehives, packaging, seasonal workers, and other variable costs (Table 2). The calculation of these costs was based on the answers of the surveyed beekeepers.

For protection against *Varroa destructor*, beekeepers usually use conventional synthetic acaricides with different active substances during the active bee season. In the period without a brood, mainly in December, the treatment with oxalic acid is scheduled, which is relatively inexpensive and does not burden production in a financial sense. Since more than half of the interviewed beekeepers consulted a veterinarian during the production cycle (55.1% versus 44.9% who did not use this type of service), the costs of engaging veterinarians were also foreseen.

The costs of maintaining the beehives included painting, wire replacement on the frames, and possibly replacement of some worn parts. Replacement costs included replacement of queen bees, frames and wax foundation in the apiary. According to the results of the research conducted, a half of the respondents replaced up to 30% of queen bees per year, which was adopted as the basis for calculating these costs. It was also planned to replace the old honey combs at the

10% level per year, or three frames with an old honey comb, and the same principle was applied in calculating the costs of replacing wax foundation.

The costs of feeding bees were calculated on the assumption that beekeepers use 10 kg of sugar and two “sugar candies” per year, based on the results of the survey, where 77.6% of the surveyed beekeepers stated that they used sugar and 78.6% used “sugar candies” for feeding the bees.

Table 2. Calculation of the expenses of beekeeping by categories of beekeeping farms (RSD).

Type of costs	Number of colonies			
	30	50	100	200
Variable costs:				
Feeding	29.580	49.300	98.600	197.200
Drugs and veterinary service	7.320	11.400	21.600	42.000
Beehive maintenance and material replacement	25.470	42.450	84.900	169.800
Moving of beehives	12.000	12.000	12.000	24.000
Packaging costs for products sold in retail	23.177	27.477	21.624	31.680
Seasonal workers	7.200	12.600	25.200	43.200
Other variable costs	12.000	12.000	18.000	18.000
Total variable costs	116.747	167.227	281.924	525.880
Fixed costs:				
Depreciation of equipment and beehives	37.500	47.500	102.000	152.000
Compulsory contributions to pension fund for permanent labour (beekeeper)	71.991	71.991	71.991	71.991
Beekeeper’s salary	270.400	270.400	270.400	270.400
Other fixed costs	28.200	31.200	31.200	31.200
Total fixed costs	408.091	421.091	475.591	525.591
Total expenses reduced for beekeeper’s salary	254.438	317.918	487.115	781.071
Total expenses	524.838	588.318	757.515	1.051.471

Source: Authors’ calculation.

Beekeepers with a smaller number of colonies decide more often to practice stationary beekeeping, although better financial results are achieved with mobile beekeeping, as a result of higher yields per beehive that can be achieved (Grgić et al., 2014; Pihler et al., 2017). Since this analysis included beekeepers that can be classified as medium and large producers in conditions characteristic for Serbia, it was assumed that the production process would involve one moving of beehives at a distance of up to 100 km. The additional reason for the calculation of the expenses based on mobile beekeeping is the results of the survey, according to which almost half of the beekeepers practiced this production system (49.0%), which is more than in the previous survey according to which only one third of beekeepers (32.6%) in the south of Serbia moves beehives (Panchev et al., 2014).

Depending on the number of hives, beekeepers used different marketing channels for honey. When they sold products to big buyers, they used returnable packaging, but for the retail of honey, appropriate packaging was necessary. This practice affected the level of packaging costs. Beekeepers with 100 beehives, who sold a significant part of their production in wholesale, did not have packaging costs for that part of production, because they used returnable packaging. Opposite to this, beekeepers with 50 beehives sold larger quantities in retail, which requires the purchase of adequate packaging, so their costs in this segment were higher (Table 2).

The majority of surveyed beekeepers (53.3%) used glass jars in which they packed one kilogram of honey. Honey is a homogeneous product, so it is hard to notice the difference between two samples of honey from different producers. Therefore, it is necessary to ensure the product recognition according to the packaging. Most beekeepers packed their honey into standard glass jars that are used for a variety of different products, which additionally made it difficult to differentiate the product. Responding to the need of their members, the Beekeeping Association of Serbia created a glass jar of specific shape, which members of this organisation used to pack their products. Using such packaging could have multiple benefits. In addition to ensuring product differentiation, this packaging could also serve as quality insurance (Pihler et al., 2017).

The variable costs included costs of seasonal workers engaged in moving hives and extracting honey. Significant sources of seasonal labour on small-scale beekeeping farms were members of a household, whereby the costs of their engagement were not included in total costs. Therefore, the engagement of "family labour" is essential for the sustainability of beekeeping farms (Yildirim and Agar, 2008; Okpokiri et al., 2015). The calculation presented in this paper follows the assumption that seasonal workers are not members of the household, and the costs of their engagement include only their income per working day.

The number of workers required for moving hives depended on their number. Costs were calculated on the assumption that for moving 25 hives two workers are required, for moving 50 hives three workers, for 100 hives six workers and for 200 hives 16 workers. A similar approach was used to calculate the required number of workers for extracting honey, but this process also depended on the applied technology and the equipment that beekeepers used.

The other variable costs included fuel costs for visiting the stationary apiary, fairs, exhibitions and conducting other business activities.

Economic indicators of honey production

The revenues and expenses presented in the conducted analysis enabled calculation of a large number of economic indicators of honey production.

Based on the variable costs and revenues, it was possible to calculate the gross margin. Gross margin shows the amount of funds available for covering fixed costs and achieving a positive financial result (Jeločnik et al., 2011). Results of the analysis showed that all farms had a positive gross margin, or that the value of production without subsidies was higher than the variable costs in all groups of beekeepers. The level of gross margin points to available funds for the payment of fixed costs and making profit. Starting from the viewpoint that a higher gross margin implies less risky business (Pejanović, 2009), it can be concluded that the increase in the number of colonies decreases the business risk.

The most important item in a structure of total costs was the permanent labour, especially beekeepers' salaries, which was classified as fixed costs. High fixed costs are a significant burden, especially for small-scale beekeeping farms. Comparing total revenues and expenses, it can be concluded that farms with 30 and 50 colonies did not generate sufficient income to cover variable and fixed costs and they had a negative financial result, while farms with 100 and 200 colonies operated with profit (Table 3). It should be pointed out, however, that if beekeepers' salaries were excluded from total expenses, all beekeeping farms would have a positive financial result, meaning that all beekeepers would generate sufficient incomes to cover all types of costs.

Table 3. Economic indicators by categories of beekeeping farms (RSD).

Economic indicators	Number of beehives			
	30	50	100	200
Revenues of sales of products	378,954	502,680	778,888	1,577,280
Total revenues	400,554	538,680	850,888	1,721,280
Variable costs	116,747	167,227	281,924	525,880
Gross margin	262,207	335,453	496,964	1,051,400
Fixed costs	408,091	421,091	475,591	525,591
Total expenses	524,838	588,318	757,515	1,051,471
Financial result	-124,284	-49,638	93,373	669,809
Economic efficiency	-	-	1.12	1.64
Profitability	-	-	10.97	38.91
Productivity of labour	-	-	71.17	302.26

Source: Authors' calculation.

The results obtained imply the necessity to determine the profitability threshold, or the production volume where revenues become equal with expenses. Production volume higher than the profitability threshold means that a farm generates profit, while a smaller production volume implies that a farm will operate at a loss. The profitability threshold in the conducted research was 68 colonies, or 1,450 kg of honey. Farms with higher number of colonies than the defined threshold generated enough revenue from the sold products and subsidies to cover all fixed and variable costs.

It is difficult to compare revenues, expenses, and financial result obtained in research with studies conducted in other countries and time periods, because these three indicators are determined by market prices of inputs and final products that were susceptible to change. However, results of the research conducted in Croatia by Knaus and Milotić (2001) are interesting. They determined that a beekeeper should have at least 168 colonies in order to achieve compensation for the work on the level of average wage in the country. The results of conducted analysis showed that in Serbia it was necessary to have 68 colonies, or to produce at least 1,450 kg of honey in order for a producer to earn a minimum wage at the republic level. If a beekeeper in Serbia strives to earn the salary on the level of national average wage, s/he should have at least 137 colonies or to produce 2,905 kg of honey.

Economic efficiency is the principle which puts total revenues and expenses incurred in production into the ratio. It was calculated for farms with a positive financial result. According to the conducted research, the level of economic efficiency increased with farm size, being the lowest on farms with 100 colonies, where economic efficiency was 1.12 (Table 3), which means that for every dinar invested in production, 1.12 dinars of income were realised. The level of economic efficiency was the highest on farms with 200 colonies. In these farms for every invested dinar, 1.64 dinars were earned. The obtained results are consistent with the ones of previous studies (Marinković and Nedić, 2010; Gugić et al., 2010), although other studies indicate higher values of the coefficient of economic efficiency (Yildirim and Agar, 2008).

Profitability points to the business outcome whereby profitable farms are those having generated more revenues than expenses or reached a positive financial result, while farms operating with a loss are considered unprofitable (Pejanović, 2009). According to the estimation of economic efficiency, beekeepers with 30 and 50 colonies operated without profit, while farms with 100 and 200 colonies were profitable.

Labour productivity is the ratio between working hours and certain financial indicators. Based on the methodology used in this analysis, the calculated productivity shows how many units of a financial result were generated per unit of working hours. Higher productivity was achieved on farms with 200 colonies.

Continuous monitoring and evaluation of the achieved results are necessary in order to improve the economic efficiency and profitability (Todorović and Filipović, 2010). The significance of the obtained results can be confirmed through dynamic analysis, which can be conducted in future research.

Conclusion

Economic indicators of honey production in apiaries with 30, 50, 100 and 200 colonies were analysed in the paper. Total revenue was calculated as the sum of incomes generated from the sale of honey and wax and subsidies per beehive. The total expenses were divided into fixed and variable. Fixed costs included depreciation of capital assets, gross compensation for the labour of beekeepers and other fixed costs. Variable costs included input costs, veterinary services, packaging, moving beehives, cost of seasonal workers and other variable costs.

Beekeeping farms with 30 and 50 colonies had a negative financial result, or their business operated at a loss. The profitability threshold was achieved at the production level of 1,450 kg of honey or with 68 colonies. Above this level of production, beekeepers can make a profit, or they can generate enough revenues to cover all costs, including the payment of salary on the level of minimum wage in the Republic of Serbia.

The values of economic indicators of economic efficiency, profitability and labour productivity showed that the production of honey on farms with 100 and 200 colonies was economically justified.

The obtained results are important for beekeepers in terms of assessing the expected economic effects of honey production, but also for the agrarian policy makers in order to understand the significance of subsidies in the production of honey. Therefore, further research suggests dynamic monitoring of selected indicators of honey production on a representative predefined sample of producers in order to determine the effects of subsidies and their development potential.

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EKONOMSKA OPRAVDANOST PROIZVODNJE MEDA U SRBIJI

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R e z i m e

Iako pčelarstvo u Srbiji ima dugu tradiciju, zainteresovanost poljoprivrednika za ovu granu poljoprivredne proizvodnje zavisi od ekonomskih koristi koje mogu da očekuju. Sagledavanje prihoda od proizvodnje meda, kao glavnog a često i jedinog proizvoda pčelarstva i troškova koji nastaju u proizvodnji predstavlja osnovu za ocenu ekonomske opravdanosti ove delatnosti. Cilj rada je da se izvrši poređenje prihoda i troškova u proizvodnji meda, kao i da se utvrdi prag rentabilnosti proizvodnje. Kalkulacija prihoda i troškova je sačinjena na osnovu podataka koji su prikupljeni anketiranjem pčelara i iz dostupnih sekundarnih izvora. Sprovedena analiza ukazuje da se prag rentabilnosti ostvaruje sa 68 pčelinjih društava, odnosno pri obimu proizvodnje od 1.450 kg meda. Vrednosti pokazatelja ekonomičnosti, produktivnosti i rentabilnosti ukazuju da je pčelarenje ekonomski opravdano na gazdinstvima sa 100 i 200 pčelinjih društava.

Ključne reči: pčelarstvo, proizvodnja meda, prihodi, rashodi, ekonomska opravdanost

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TOTAL FACTOR PRODUCTIVITY (TFP) OF PRODUCTIVE RESOURCES USED IN HOMESTEAD POULTRY BROILER FARMS IN NIGER STATE OF NIGERIA

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Abstract: The present research measured the total factor productivity (TFP) of productive resources used in homestead poultry broiler farms in Niger State of Nigeria, using a structured questionnaire complemented with an interview schedule to collect cross-sectional data from a drawn sample size of 97 active broiler producers *via* the multi-stage sampling design. The data analyses were performed using descriptive and inferential statistics. Findings from the study showed evidence of a productive labour force in the enterprise, literate farming population with a sustainable household size typical of African agrarian settings. The enterprise was found to be profitable in the studied area. Furthermore, findings showed that more than half of the sampling population was productive in the utilisation of their input resources, which may be due to technical awareness of the modern poultry management techniques in the studied area. Thereafter, it was observed that gender status, experience, capital source and operational capital were the factors affecting TFP of the farmers. Therefore, the study recommends gender sensitisation and the need for public private partnership synergy to explore the untapped potentials in this sub-sector in the studied area as almost half of the farmers were found not to be productive in the utilisation of their resources.

Key words: homestead, poultry, resources, TFP, Nigeria.

Introduction

According to FAO as reported by SAHEL (2015), growing populations, economies and incomes are fuelling an ongoing trend towards higher consumption of animal protein in developing countries. The FAO has forecasted that Nigerians

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are expected to consume two thirds more of animal protein, with meat consumption rising nearly by 73%. As in 2013, the estimated worth of Nigerian poultry industry which comprised approximately 165 million birds which produced 650,000 metric tonnes of eggs and 290,000 metric tonnes of poultry meat stood at ₦80 billion ($600 million). The sector has been receiving continuous support and attention from policy makers. In the year of 2003, the Federal government banned the importation of chicken (with the exception of day-old chicks), thus, spurring growth in domestic poultry production.

Statistics have shown that the total production of poultry product has been exhibiting a cyclical trend from the year of 2009 to the date with the changes being attributed to an increase in plant size and not productivity which remained stagnant over the past four to five decades (FAO, 2016). However, statistics highlighted that between 2009 and 2011, over 3 million metric tonnes worth of poultry products were imported into the Republic of Benin, with the preponderance of these products ending up in the Nigerian market (SAHEL, 2015). If this is reflected in overall assumptions, estimated poultry meat consumption in Nigeria is approximately 1.2 million metric tonnes. This implies inadequacy in the present production and supply chain of poultry products. However, previous studies have shown that an increase in livestock production in Nigeria was propelled by the average expansion rather than by higher intensification and productivity of resources (Olayide, 1976; Ezeh et al., 2012).

In spite of these challenges, an annual growth of 20% in the poultry industry between 2010 and 2020 which will be driven by a rapidly growing middle class and the country's large population has been projected by analysts (SAHEL, 2015). Despite the fact that the country's poultry industry is extremely fragmented with most of the birds being raised in 'backyards' or on poultry farms with less than 1,000 birds, the number of researches conducted (e.g. Ajetomobi and Binuomote, 2006; Salman et al., 2010; Banjoko et al., 2014) has demonstrated the importance of the sub-sector to the economy of the country.

In order to make the sub-sector vibrant and secure a lead in the market, there is a need to address the challenge of total factor productivity (TFP) of poultry producers in the country. In lieu of the aforementioned, Niger State was chosen as a pilot site for this research given the cost constraints of the researchers. The TFP, as a measure of overall productivity, has gained recognition not only for its theoretical correctness, but also for its peculiarity among policymakers and economic analysts, as TFP provides the society with an opportunity to increase the society welfare. The broad objective was to determine the TFP of broiler farmers in the studied area, while the specific objectives were to: describe the socio-economic profile of the broiler producers; estimate the costs and incomes of the poultry enterprise in the studied area; determine the TFP and the factors influencing TFP of broiler producers; and, identify and x-ray the problems affecting the poultry enterprise in the studied area.

Materials and Methods

The study was conducted in Niger State of Nigeria, and the coordinates of the State are latitudes 8°20'N and 11°30'N of equator and longitudes 3°30'E and 7°20'E of the Greenwich meridian time. The vegetation of the State is northern guinea savannah with sparse of southern guinea savannah. Agriculture is the major occupation in the study area complemented with civil service jobs, artisanal, craft work, *ayurveda* medicine and petty trade. The research relied on cross sectional data obtained from 97 active homestead poultry broiler farms drawn from the studied area sampling frame (192) using a multi-stage sampling design. The sampling procedures were: convenient selection of Kuta agricultural zone out of the 3 existing agricultural zones in the State due to time and cost constraints of the researchers; purposive selection of two Local Government Areas (LGAs) *viz.* Chanchaga and Bosso due to high density of poultry entrepreneurs coupled with readily available demand driven-market; proportionate sampling of 50% of the respondents across the board of the selected LGAs in the sampling frame provided by Niger State Agricultural and Mechanization Development Agency (NAMDA); and, a representative sample size of 97 active broiler farmers using the simple random technique were drawn for the study. The data were elicited using a structured questionnaire complemented with the interview schedule on a fortnightly basis during the 2016 production period. The collected data were analysed using descriptive and inferential statistics. The first and last, second and third objectives were achieved using descriptive statistics, cost concepts and income measures; and, the conventional approach of measuring TFP developed by Key and Macbride (2003) and the Tobit regression model.

Table 1. A sampling frame of active poultry broiler producers.

LGAs	Population	Sample size
Bosso	93	47
Chanchaga	99	50
Total	192	97

Source: NAMDA, 2016.

Empirical models

1. Cost concepts and income measures

Following Subba et al. (2004; 2016), the cost concepts and income measures are specified below:

a. *Cost concepts*: Costs related to broiler production were split up into various cost concepts such as A_1, A_2, B, C and D:

Opportunity/Implicit cost: costs of self-owned and self-employed resource i.e. imputed cost;

Accounting/Explicit cost: costs for purchasing and hiring of inputs and input services i.e. paid out costs/cash costs/nominal/money cost;

Economic cost: Opportunity cost + Accounting cost;

Cost A_1: The following items are included in Cost A_1:

Wages of hired labour;

Market rate of feeds;

Market rate of brooding stocks, litter, H_2O, kerosene, etc.;

Electricity tariff;

Market value of drugs and vaccines;

Land revenue, cess and other tax;

Depreciation on farm implements/equipments;

Interest on working capital;

Miscellaneous expenses;

Cost A_2: Cost A_1 + rent paid for leased-in land;

Cost B: Cost A_1 or A_2 + interest on fixed capital excluding land + rental value of owned land;

Cost C: Cost B + imputed value of family labour;

Cost D: Cost C + 10% of TVC as management cost (Sidharth and Pankaj, 2012).

b. Income measures

These are the returns over different cost concepts. Different income measures were derived using the cost concepts. These measures are given below:

Farm business income = Gross income – Cost A_1 or A_2 .... (1)

Family labour income = Gross income – Cost B .... (2)

Net income = Gross income – Cost D .... (3)

Farm investment income = Farm business income – Imputed value of family labour – Imputed management cost (OR) Net income + Imputed rental value of owned land

Return on Naira invested (ROI) $= \frac{\text{Gross margin}}{\text{Total variable cost}}$ …....…………………... (4)

Rate of return on capital invested (RORCI) $= \frac{Net\ farm\ income}{Total\ cost}$ ……...……. (5)

Note: Unit of plant = 200 birds (Subba et al., 2004; 2016)

Plant = Enterprise (Sidharth and Pankaj, 2012)

Total factor productivity (TFP)

Following Key and Macbride (2003), the TFP approach adopted is given below:

$$\text{TFP} = \frac{Y}{TVC} \quad \text{.......... (6)}$$

$$\text{TFP} = \frac{Y}{\sum P_i X_i} \quad \text{.......... (7)}$$

where, Y is output quantity (kg), TVC is total variable cost, P_i is the unit price of the i^th variable input and X_i is the quantity of the i^th variable input. This methodology neglects the TFC as it does not affect the profit maximisation nor the resource use efficiency conditions as the study focused on small-scale farmers. Total fixed cost is constant as it is sunk.

Deducing from cost theory:

$$\text{AVC} = {TVC}/{Y} \quad \text{.......... (8)}$$

where, AVC is average variable cost in Naira (₦). Therefore, the transpose of AVC will be TFP:

$$\text{TFP} = \frac{Y}{TVC} = \frac{1}{AVC} \quad \text{.......... (9)}$$

As such, TFP is the inverse of the AVC. The partial productivity estimate is the marginal product given as MP = $\Delta TFP/\Delta X$.

Tobit model

The original Tobit model developed by James Tobin, a Nobel laureate economist (Tobin, 1958) was adopted for this study and it is given below:

$$Y_i^* = \alpha + X\beta + \varepsilon_i \quad \text{.......... (10)}$$

where Y_i* is a censored variable. Now,

$Y_i = 0$ *if* $Y_i^* \leq 0$

$= Y_i^*$ *if* $Y_i^* > 0$

$$Y_i^* = \alpha_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 \ldots\ldots\ldots\ldots\ldots\ldots + \beta_n X_n + \varepsilon_t \quad \text{.......... (11)}$$

where:

Y_i* = TFP index of the i^th farmer;

X_1 = Gender (male = 1, female = 0);

X_2 = Marital status (married = 1, otherwise = 0);

X_3 = Age (year);

X_4 = Household size (number);

X_5 = Educational level (year);

X_6 = Farming experience (year);

X_7 = Farm ownership (yes =1, otherwise = 0);

X_8 = Main occupation (farming = 1, otherwise = 0);

X_9 = Source of capital (own saving = 1, otherwise = 0);

X_{10} = Access to credit (yes = 1, otherwise = 0);

X_{11} = Extension contact (yes = 1, otherwise = 0);

X_{12} = Co-operative membership (yes = 1, otherwise = 0);

X_{13} = Farm location (urban = 1, otherwise = 0);

X_{14} = Disease outbreak (yes = 1, otherwise = 0);

X_{15} = Family labour (manhour);
X_{16} = Hired labour (manhour);
X_{17} = Medication (kg);
X_{18} = Litter (kg);
X_{19} = H_2O (litre);
X_{20} = Kerosene (litre);
X_{21} = Electricity (kW/hr);
X_{22} = Feeds (kg);
X_{23} = Chick density (kg);
X_{24} = Income (₦);
α = Intercept;
β_{1-n} = Parameter estimates;
ε_i = Error term.

Kendall's coefficient of concordance (W)

Following Sadiq et al. (2017), the Kendall's coefficient of concordance developed by Kendall and Smith (1939 a, b) and Wallis (1939) is given below:

$$W = \frac{12S}{k2n\ (n2\ -1) - kT} \quad \ldots\ldots (12)$$

where:
S = Sum over all subjects;
k = Number of respondents ranking the attributes or objects;
n = Number of attributes or objects that are evaluated by respondents;
T = Tie-correction factor;

$$T = \sum (t_k^3 - t_k) \quad \ldots\ldots (13)$$

't_k' is the number of tied ranks in each (k) of g groups of ties. The sum is computed over all groups of ties found in all m variables of the data table. T is 0 when there are no tied values.

The Chi^2 (χ^2) statistic is given as follows:

$$\chi^2 = k\ (n\ -1)\ W \quad \ldots\ldots (14)$$

where:
k = Number of respondents;
n = Number of objects or attributes being ranked;
W = Kendall's coefficient of concordance (KCC).

Friedman's chi-square statistic

The Friedman's chi-square statistic is given below (Friedman, 1937):

$$\chi^2_r = k\ (n-1)\ W \quad \ldots\ldots (15)$$

where:
χ^2_r = Friedman's chi^2 statistic;
k = Number of respondents;
n = Number of objects or attributes being ranked;
W = Kendall's coefficient of concordance (KCC).

The mean benchmark for constraint assessment

In order to have better insights into the constraints, the assessment mean model adopted by Aydin and Tasci (2005) as reported by Purnomo and Lee (2010) was used. The mean of 3.25 was determined after identifying the critical level: 2.5 plus (3 interval/4 categories = 0.75).

1. *Average variance extraction (AVE) and composite reliability (CR)*

The AVE formula suggested by Hair et al. (1998) is given below:

$$\boldsymbol{AVE} = \frac{(\sum_{i=1}^{n} \lambda_i^2)}{(\sum_{i=1}^{n} \lambda_i^2) + (\sum_{i=1}^{n} \delta_i)} \quad \text{.......} (16)$$

The formula for calculating composite reliability is specified as follows:

$$\boldsymbol{CR} = \frac{(\sum_{i}^{n} \lambda_i)^2}{(\sum_{i}^{n} \lambda_i)2 + (\sum_{i=1}^{n} \delta_i)} \quad \text{.......} (17)$$

where λ is the standardised factor loading and δ is the indicator measurement error.

Results and Discussion

The socio-economic profile of the broiler farmers in the studied area

Table 2 shows the socio-economic profiles of the poultry broiler farmers in the studied area. The results showed that most of the labour force that participated in the enterprise was active and economically virile; maintained a fair family size typical for African settings and had few years of poultry management experience as indicated by the mean age of 35.22 ± 7.34; mean family size of 7 ± 3.9 and mean experience of 5 ± 4.2, respectively. Female farmers' participation in the enterprise was very marginal when compared to their male counterpart, which may be attributed to economic and religion constraints; and married people were the majority in the sampling population that relied on the enterprise for livelihood sustenance. The literacy level of the farming population was very high. The majority possessed title of ownership i.e. they owned the farms where they raised their birds and few were full-time poultry entrepreneurs. The farmers' access to credit, extension contacts and social participation were found to be very poor and most of the farmers used their own savings as the capital for the poultry investment during the period of study. A slight difference in the results was observed between the number of farms located in the rural and urban areas and most of the farms were affected by the outbreak of poultry diseases during the period of study. With the exception of the source of capital, discrepancies were observed in the distribution proportion of each of the socio-economic characteristics considered as evident by their chi^2 statistics probability levels which were different from zero at the 10% probability level.

Table 2. The socio-economic profile of the broiler farmers.

Variables	Frequency	Percentage	Variables	Frequency	Percentage
Age			Total	97	100 [38.36***]
≤ 19	1	1.0	Occupation		
20–29	27	27.8	Farmer	26	26.8
30–39	39	40.2	Farmer/Artisanal	38	39.2
40–49	28	28.9	Farmer/Civil servant (CS)	5	5.2
50–59	2	2.1	Farmer/Artisanal/CS	28	28.9
Total	97 (35.22±7.3)	100 [59.65***]	Total	97	100 [23.78***]
Household size			Access to credit		
≤ 3	8	8.2	Yes	17	17.5
4–6	52	53.6	No	80	82.5
7–9	25	25.8	Total	97	100 [40.92***]
≥ 10	12	12.4	Extension contact		
Total	97 (6.8±3.9)	100 [48.86***]	Yes	31	32
Experience			No	66	68
≤ 3	49	50.5	Total	97	100 [12.63***]
4–6	25	25.8	Social participation		
7–9	9	9.3	Yes	22	22.7
≥ 10	14	14.4	No	75	77.3
Total	97 (4.9±4.17)	100 [39.21***]	Total	97	100 [28.96***]
Gender			Farm location		
Male	84	86.6	Urban	47	48.5
Female	13	13.4	Rural	50	51.5
Total	97	100 [59.97***]	Total	97	100 [0.09^{NS}]
Marital status			Disease outbreak		
Married	73	75.3	Yes	70	72.2
Single	24	24.7	No	27	27.8
Total	97	100 [142.79***]	Total	97	100 [19.06***]
Education			Source of capital		
Non-formal	16	16.5	Own savings	92	94.8
Formal	81	83.5	Formal credit	5	5.2
Total	97	100 [43.56***]	Total	97	100 [78.03***]
Farm ownership					
Owned	79	81.4			
Rented	18	18.6			

Source: Field survey, 2016. Note: *** & NS are 1% risk level and non-significant; while values in ( ); [ ] are mean and standard error; and, chi^2 respectively.

Cost concepts and income measures of poultry broiler enterprise in the studied area

The poultry farmers, like any other entrepreneurs, would be interested in the profitability of the farm enterprise, and for this purpose, attempts were made to estimate the cost incurred and the accrued revenue to the farmers' efforts.

Table 3 shows the cost concepts and income measures of a poultry broiler enterprise in the studied area. The disaggregation figures showed the incurred economic and accounting costs of an enterprise to be ₦225774.20 and ₦163461.80 respectively; and the accrued accounting revenue of ₦307327.40. The proportions of incurred total economic variable cost (TEVC) and total economic fixed cost (TEFC) in the economic cost of an enterprise were 53.70% and 46.30% respectively; while the proportions of incurred total accounting variable cost (TAVC) and total accounting fixed cost (TAFC) in the accounting cost of an enterprise were 58.25% and 41.75%, respectively.

Table 3. Cost concepts and income measures of broiler enterprise.

Items	Quantity	Unit price (₦)	Amount (₦)	Items	Amount (₦)
Variable costs				Total fixed accounting cost	68252.06
Family labour	52.13 manhours	200	10426.29	Total accounting cost	163461.80
Hired labour	26.45 manhours	200	5289.92	Total variable economic cost	121236.10
Chicks	239.64	204.64	49040.33	Total fixed economic cost	104538.10
Feeds	135.87 kg	113.36	15402.17	Total economic cost	225774.20
Litter	1577.37 kg	10	15773.66	Cost A_1	154899.40
H_2O	46.36 litres	1	46.36	Cost A_2	179061.80
Kerosene	6.48 litres	150	971.55	Cost B	203224.30
Electricity	230.32 kw/hr	14	3224.43	Cost C	213650.50
Drugs	1.94 kg	800	1552.93	Cost D	225774.2
Vaccines	-	-	3036.45	Income measures	
Veterinary services	-	-	872	Implicit revenue	-
IV of interest on working capital	12 % @ 130000	-	15600	Explicit revenue	307327.40
Total variable cost (TVC)			121236.10	Economic revenue	307327.40
Fixed costs				Accounting gross margin	212117.60
Depreciation on capital items			44089.65	Accounting net farm income	143865.50
Economic rent (lease-in)			24162.40	AROI	2.23
Imputed economic rent (owned land)			24162.40	ARORCI	0.88
Imputed managerial cost	10% of TVC		12123.61	Accounting cost of production	817.31
Total fixed cost (TFC)			104538.10	Farm business income	128265.50
Total cost (TC)			225774.20	Family labour income	104103.10
Returns				Economic gross margin	186091.30
Manure quantity	732.74 kg	10	7327.37	Economic net farm income	81553.21

Table 3. Continued.

Items	Quantity	Unit price (₦)	Amount (₦)	Items	Amount (₦)
Broiler quantity	200 birds	1500	300000	Farm investment income	117839.20
Total revenue (TR)			307327.40	EROI	1.54
Cost concepts				ERORCI	0.36
Total variable opportunity cost			26026.29	Economic cost of production	1128.87
Total fixed opportunity cost			36286.01		
Total opportunity cost			62312.30		
Total variable accounting cost			95209.79		

Source: Field survey, 2016. Note: IV means Imputed value and 1$ = ₦260.

Furthermore, the profitability decomposition figures revealed an economic gross margin cum net farm incomes of ₦186091.30 and ₦81553.21, respectively, while the accounting gross margin cum net farm incomes were ₦212117.60 and ₦143865.50, respectively. The economic and accounting ROIs were 1.54 and 2.23 respectively, implying that for every ₦1 invested in the enterprise, the invested ₦1 was returned, and economic and accounting profits of ₦0.54kobo and ₦1.85kobo respectively were gained. This profit margin should stimulate financing from the lending institutions because if poultry farmers in the studied area are funded with ₦130000 at a commercial interest rate of 12%, the farmer will return the principal of ₦130000, an interest rate of ₦15600 and will still retain ₦161727.40. Therefore, at the enterprise level, it can be concluded that poultry farming is a profitable venture in the studied area because of the remunerative or considerable profit margin. The rate of return per unit of capital invested (RORCI) which indicates what is earned by the business through capital outlay revealed an economic RORCI (36%) and accounting RORCI (88%) that were greater than the prevailing commercial bank lending rate of 12%, implying that if a poultry broiler entrepreneur takes a loan from the bank to finance poultry enterprise, in respect of economic and accounting RORCIs, he/she will be 24% and 76%, respectively, better-off on every one naira spent after paying the loan at the prevailing interest rate.

The measurement of broiler farmers' TFP and factors determining TFP

The summary statistics of the TFP showed that most (48.5%) of the farmers were not productive as their TFP indices were below the optimal scale, which indicated poor input mix allocation in the production process (Table 4a). Only 20.62% of the farmers were found to be optimally productive as their TFP indices hovered around the optimal scale. Although these sets of farmers were productive, their output index was just marginally higher than the input index. Furthermore, 30.91% of the broiler farmers fell within the super-optimal category, an indication of high productivity. In addition, it depicts how super-efficient these farmers were in the utilisation of their input mix which yielded high broiler output in their respective farms. It can be inferred that marginally above average of the farming population they were productive in the utilisation of their productive resources.

Table 4a. Distribution of TFP index of broiler farmers in the studied area.

TFP Index	Frequency	Percentage
Sub-optimal (< 1.00)	47	48.5
Optimal (1.00–1.09)	20	20.62
Super-optimal (≥ 1.10)	30	30.91
Total	97	100
Mean	0.981	
Minimum	0.219	
Maximum	2.504	
SD	0.301	
CV	0.307	

Source: Field survey, 2016.

The MLE determinants of TFP of broiler farms in the studied area are shown in Table 4b. The significance of the LR chi^2 at 1% degree of freedom implies that the parameter estimates were different from zero at the 10% probability level, and the model is best fit for the specified equation. In addition, the multicollinearity test exonerated the explanatory variables from the problem of a collinear relationship as established by their respective variance inflation factors (VIF) which were less than 10.00 VIF benchmark value. However, the test for normality of the residuals showed abnormal skew in the distribution of the error terms as evidenced from the probability value of t-statistic value (42.00) which is different from 10% risk level. However, non-normality is not considered a serious problem given that data are not normally distributed in most situations. The socio-economic variables and production inputs found to have a significant influence on TFP were gender, experience, source of capital and income; and, chick density, feeds, hired labour, medication, litter, electricity, H_2O and kerosene, respectively. The marginal implications of a unit increase in experience and being a female broiler farmer; and, a unit increase in income level and using owned/equity capital would decrease TFP by 0.00004 and 0.00047; and, would increase TFP by 0.00012 and 0.00054, respectively. In most cases, experienced farmers are conservative when compared to young ones who are innovative, and they would likely stick to the archaic poultry management system, thus affecting their TFP. Similarly, experienced farmers are found of exhibiting complacency thereby jettisoning innovative poultry management techniques. In addition, experienced farmers hardly devote time supervising their farms as after series of achievements in the enterprise they diverse most of their attention/commitment to profitable new enterprise(s) (mostly fish farming), hence, affecting their efficiency in optimising TFP. Limited access of female farmers to productive resources due to religion and cultural barriers leads to negative consequences on female broiler farmers in optimising their TFP. Farmers whose investment is their equity capital would be judicious in the utilisation and protection of their equity to optimise TFP (profit maximisation) as there is no insurance for loss of their economic capital. Additional increase in the stream of the farmers' income level would encourage farmers to defer their present consumption by investing more in the poultry enterprise in anticipation for higher future returns, thus increasing the TFP efficiency.

Table 4b. Factors determining TFP of broiler farmers in the studied area.

Variables	Coefficients (MPP)	Standard error	t-stat	VIF
Constant	-0.00134	0.00093	1.445^{NS}	-
Gender	-0.00047	0.00026	1.757*	1.478
Marital status	-7.3613E-05	0.00019	0.395^{NS}	2.162
Age	1.70402E-05	1.3883E-05	1.227^{NS}	2.795
Household size	-1.8302E-05	2.24005E-05	0.817^{NS}	1.916
Education	0.000175	0.00026	0.680^{NS}	1.563
Experience	-4.00156E-05	2.1409E-05	1.869*	2.861
Farm ownership	0.000229	0.00021	1.111^{NS}	1.520
Occupation	0.000112	0.00017	0.661^{NS}	1.523
Source of capital	0.000542	0.00031	1.750*	1.941
Access to credit	-0.000137	0.00020	0.676^{NS}	1.967
Extension contact	0.000115	0.00018	0.643^{NS}	1.396
Co-operative mem.	9.0009E-05	0.00022	0.407^{NS}	1.460
Farm location	4.8116E-05	0.00013	0.361^{NS}	1.590
Disease outbreak	7.6899E-05	0.00016	0.477^{NS}	1.630
Family labour	6.2601E-07	1.41257E-06	0.443^{NS}	1.673
Hired labour	-8.3846E-06	5.06618E-06	1.655*	1.389
Medication	-5.7225E-05	2.26372E-05	2.528**	1.387
Litter	-1.6943E-08	1.00534E-08	1.685*	2.733
H_2O	8.8348E-06	2.21623E-06	3.986***	1.401
Kerosene	6.5238E-06	3.18883E-05	2.046**	1.252
Electricity	-1.0663E-06	6.33623E-07	1.683*	1.892
Feeds	3.2339E-06	1.26741E-06	2.552**	1.791
Income	0.000121	6.25815E-05	1.926*	1.893
Chick density	-4.8632E-07	1.70127E-07	2.859***	1.705
LR chi^2	355.24***			
Normality test			41.99***	

Source: Field survey, 2016.

The marginal implications of unit increase in the utilisation of feeds, H_2O and kerosene would decrease the broiler TFP by 3.23E-06, 8.84E-06 and 6.52E-05 respectively, an indication of marginal efficiency in the utilisation of the aforementioned inputs. However, the marginal implications of unit increase in the stock density of chicks, use of hired labour, litter, medication and electricity would decrease broiler TFP by 4.86E-07, 8.38E-06, 1.69E-08, 5.72E-05 and 1.07E-06 respectively, an indication of marginal inefficiency in the utilisation of these productive resources.

Constraints of broiler farmers in the studied area

A cursory review of the results identified five problems *viz.* epileptic power supply, high cost of housing, high cost of feeds, capital paucity and high cost of brooding stocks, to be the very severe constraints affecting poultry broiler production in the studied area as their mean scores exceeded the severe benchmark score of 3.25. The remaining identified constraints were not a major threat as their mean score values were below the benchmark score. In descending order, the major constraints where ranked 1st to 5th while the minor constraints where ranked 6th to 11th. The grand mean value indicated that the respondents had strong perception on the identified major problems as the barriers affecting the poultry enterprise in the studied area. In addition, 87.37% of the sampling population chose the first five problems as the major problems affecting their poultry enterprises. With respect to the ranking, the significant estimated KCC value of 0.728 indicated strong agreement among the respondents with respect to this ranking (Table 5a).

To find the common factors affecting poultry farms in the studied area, the 11 identified constraints were subjected to factor analysis (Table 5a). The empirical result showed that the sample size achieved good sampling adequacy as evidenced by the KMO test value of 0.718 and the Bartlett's test of sphericity which indicated that non-zero correlations existed at the 1% significance level i.e. the correlation matrix was not an identity matrix. The latent criterion results indicated that the 11 variables subjected to the exploratory factor analysis should be extracted to form four dimensions as their eigen-values were greater than the cut-off criterion value of 1 considered satisfactory in social sciences (Hair et al., 2006 as cited by Sadiq et al., 2017), and in addition, they accounted for 66.87% of the variation in the data. The estimated Cronbach's alpha test values across the four factors were greater than the cut-off point of 0.60 suggested by Churchill (1979) to be appropriate for exploratory research, hence, an indication of high internal consistency and reliability of the poultry constraint scales. According to Francis et al. (2000), the behaviour of individual items in relation to others within the same factor provides confirmation of content validity because the highest factor loading is central to the domains assessed by these factors. These evidences proved the appropriateness of the sample for the multivariate analysis. The respective factor loadings of the extracted factors excluded those whose absolute loading values were less than 0.40. The extracted four factors were named market barrier (F1), institutional barrier (F2), sanitary barrier (F3) and management barrier (F4).

Table 5a. Constraints affecting broiler farmers in the studied area.

Constraints	Mean	Market barrier (F1)	Institutional barrier (F2)	Sanitary barrier (F3)	Management barrier (F4)
Paucity of capital	3.36 (4th)	0.759			
Cost of housing	3.58 (2nd)	0.738			
High labour cost	3.18 (8th)	0.702			
High feed cost	3.52 (3rd)	0.695			
High cost of brooding stock	3.32 (5th)	0.513			
Inadequate veterinary service	2.19 (13th)		0.847		
Inadequate extension service	2.28 (11th)		0.843		
Mortality rate	2.62 (10th)			0.812	
Pest and diseases	2.23 (12th)			0.783	
Poor production management	2.74 (9th)				0.807
Epileptic power supply	3.59 (1st)				0.711
Expected mean $(\overline{X})$	3.25 (7th)				
Kendall's coefficient (KCC)	0.728				
Chi^2 (χ^2)	618.01***				
Friedman's Chi^2 (χ^2)	618.01***				
Eigen-value		2.719	2.203	1.273	1.160
% of variance		24.72	20.03	11.57	10.55
Cronbach's alpha		0.719	0.821	0.601	0.650
Kaiser-Meyer-Olkin test (KMO)	0.718				
Bartlett's test of sphericity (χ^2)	281.92***				

Source: Field survey, 2016.

The first factor named "market barrier" with an eigen-value of 2.72 was highly loaded on capital paucity, high cost of housing, high labour cost, high feed cost and high cost of brooding stocks, and explained 24.72% variance, showing the farmers' concern for poor market outlet for broiler products, thus, the need for efficient market which would guarantee them remunerative prices for their output. The second factor, named "institutional barrier" had an eigen-value of 2.20, accounted for 20.03% variance and highly loaded on poor veterinary and extension service delivery, displayed the farmers' concern about inaccessibility and inadequacy of technical support from the government institution in the studied area. The third factor named "sanitary barrier" which captured a mortality rate and pest and disease outbreaks, with an eigen-value of 1.27 and 11.57% explained variance, showed farmers' apprehension on poor sanitary measures which can likely wipe out their farms, thus, a call for frequent quarantine to curtail these disasters/menaces. The last factor named "management barrier" loaded on poor production management and epileptic power supply with an eigen-value of 1.16 and accounted for 10.55% of variation showed the farmers’ concern on management ineptitude and call for overhauling of agribusiness policies in order to sustain the poultry sub-sector in the studied area.

Since the measurement model has acceptable fits, the four-factor constructs with their respective indicators were used to estimate CFA. In addition, unidimensionality was achieved as evidenced by the small size of the modification indices and estimated residuals. A perusal of Table 5b showed all the criteria of goodness of fit statistics and other measures of statistics to be acceptable for the CFA structural equation model. It is worth noting that one could ignore the absolute fit index of minimum discrepancy chi^2 if the sample size is greater than 200 (Jöreskog and Sörbom, 1984; Hair et al., 1998).

Table 5b. CFA goodness of fit statistics.

Category	Fit statistic	Value	Acceptance level	
Absolute fit	Discrepancy chi^2 (χ^2)	0.1423	> 0.05	Wheaton et al. (1977); Bentler (1989)
	RMSEA	0.053	< 0.08[a] or 0.10[b]	Browne and Cudeck (1993)[a]; Hair et al. (1998)[b]
	GFI	0.933	> 0.90	Joreskog and Sorbom (1984)
Incremental fit	AGFI	0.853	> 0.80	Henry and Stone (1994); Scott (1994)
	CFI	0.965	> 0.90	Bentler (1990)
	NFI	0.983	> 0.90	Bollen (1989); Bentler and Bonett (1980)
	TLI/NNFI	0.939	> 0.90	Bentler and Bonett (1980)
	IFI	0.969	> 0.90	-
	RFI	0.766	-	-
	SRMR	0.0798	< 0.10	-
	PNFI	0.438	-	-
Parsimonious fit	χ^2/df	29.71	< 3.0	Marsh and Hocevar (1985)

Source: SEM computer print-out. Note: RMSEA = Root mean squared error of approximation; GFI = Goodness-of-fit index; AGFI = Adjusted goodness-of-fit index; CFI = Comparative fit index; NFI = Normed fit index; TLI = Tucker-Lewis index; NNFI = Non-normed fit index; IFI = Incremental fit index; SRMR = Standardised root mean square error residual; and PNFI = Parsimony-adjusted NFI.

A cursory review of the convergent validity showed all the constructs to have good convergent validity as each indicator of the construct factor loadings (CFL) exceeded 0.50 with their respective factor loadings as reflective indicators exceeding 0.60. The average variance extraction (AVE) ranged from 0.50 to 0.88, while the composite reliability (CR) ranged from 0.67 to 0.94. The results of the discriminant validity showed each AVE construct to be higher than its squared correlation with other constructs. The empirical results showed that the factor loadings of factors 1, 2, 3, and 4 accounted for 73%, 65%, 77% and 82% of the average variance in the market, institutional, sanitary and managerial barriers, respectively. Therefore, relying on these results, we can conclude that the measurement model exhibits a high degree of convergent and discriminant validities (Table 5c).

Table 5c. CFA for convergent and discriminant validity of constraints.

Construct	CFL	AVE	CR	Factor correlations			
				F1	F2	F3	F4
Market (F1)	0.719	0.70	0.92	0.84			
Institutional (F2)	0.821	0.78	0.92	0.160	0.88		
Sanitary (F3)	0.601	0.88	0.94	0.182	0.009	0.94	
Management (F4)	0.650	0.50	0.67	1.719	1.184	0.371	0.71

Source: SEM computer print-out. Note: All items loading in CFA were significant at $P < 0.001$ level. The diagonal values are the square roots for each construct.

The path analysis was used to estimate simultaneously the processes of the influence of the variables on others, direct, indirect and total effects of the variables. The results showed that each latent variable had a direct effect on the items loaded on them. The latent variables *viz.* market restraint and institutional restraint had correlation; likewise the latter had correlation with sanitary barrier and managerial restraint.

Conclusion

The farming population was economically virile and literate, possessed fair household sizes and most of the farms they operated on were their personal assets. However, they are faced with limitation of access to credit, extension service delivery and poor social participation; and, the farming population is skewed towards male gender. The enterprise was found to be profitable. More than half of the sampled population was productive in the use of their resources as their productivity was found to range between optimal and super optimal levels i.e. equal or above the TFP index frontier scale, which may be due to technical awareness of the modern poultry management techniques in the studied area. However, the empirical identified issues causing inefficiency in the farmers' productivity were gender, experience, capital source, chick density, hired labour, medication, litter and electricity consumption. Based on the above scenario, the following recommendations were made:

Tacit sensitisation of the community leaders on the active role of women in agricultural enhancement and the successes so far recorded in other parts of the country should be a reference so that more women in the studied area will be able to participate in poultry enterprise, thus, easing them out of the vicious cycle of poverty.

The mechanism of public-private partnership should be put in place in order to make this sub-sector more vibrant and sustainable in the studied area and the state in general.

Extension agents need to educate farmers more on the technical know-how of poultry management so that the almost half of the remaining farmers can optimise their productivity by enhancing their efficiency in the allocation of their productive resources in the studied area.

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UKUPNA FAKTORSKA PRODUKTIVNOST (UFP) PROIZVODNIH RESURSA NA GAZDINSTVIMA DOMAĆIH ŽIVINSKIH BROJLERA U DRŽAVI NIGER U NIGERIJI

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R e z i m e

Ovim istraživanjem je merena ukupna faktorska produktivnost (UFP) proizvodnih resursa korišćenih na gazdinstvima, koja gaje brojlere u državi Niger u Nigeriji. Za prikupljanje podataka korišćen je strukturirani upitnik upotpunjen intervjuom. Uzorkom je obuhvaćeno 97 aktivnih uzgajivača brojlera. Primenjen je višefazni plan uzorkovanja. Analiza podataka je izvršena primenom deskriptivne i inferencijalne statistike. Rezultati istraživanja ukazuju na postojanje produktivne radne snage u ovoj liniji proizvodnje, odnosno pismenoj poljoprivrednoj populaciji sa održivom veličinom domaćinstva tipičnom za afričke agrarne sredine. Utvrđeno je da je ova linija proizvodnje u ispitivanom području profitabilna. Pored toga, rezultati su pokazali da je više od polovine uzorkovane populacije bilo produktivno u korišćenju svojih ulaznih resursa, što može biti posledica osvešćenosti o modernim tehnikama upravljanja živinarskom proizvodnjom u ispitivanom području. Uočeno je zatim da su rodni status, iskustvo, izvor kapitala i operativni kapital, faktori koji utiču na UFP poljoprivrednika. Prema tome, istraživanjem se preporučuju rodna senzibilizacija i ukazuje na potrebu za sinergijom javno-privatnog partnerstva, kako bi se istražili neiskorišćeni potencijali u ovom podsektoru u ispitivanom području, s obzirom da gotovo polovina poljoprivrednika nije produktivna u korišćenju svojih resursa.

Ključne reči: kuća sa okućnicom, živina, resursi, UFP, Nigerija.

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Books

Steel, R.G.D., & Torrie, J.H. (1980). *Principles and procedures of statistics*. New York: McGraw-Hill Book Company.

Book chapter

Bell, R.L., Quamme, H.A., Layne, R.E.C., & Skirvin, R. M. (1996). Pears. In J. Janick & J.N. Moore (Eds.), *Fruit breeding, Volume I: Tree and tropical fruits.* (pp. 441-514). New York: John Wiley and Sons, Inc.

Proceedings

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Knjiga

Steel, R.G.D., & Torrie, J.H. (1980). *Principles and procedures of statistics*. New York: McGraw-Hill Book Company.

Poglavlje u knjizi

Bell, R.L., Quamme, H.A., Layne, R.E.C., & Skirvin, R.M. (1996). Pears. In J. Janick & J.N. Moore (Eds.), *Fruit breeding, Volume I: Tree and tropical fruits.* (pp. 441-514). New York: John Wiley and Sons, Inc.

Zbornik

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Tabele
Tabele obeležene arapskim brojevima (1, 2, itd.) praćene naslovom treba da se nalaze na odgovarajućem mestu u tekstu, u fontu 9. Maksimalna širina tabela treba da bude 13 cm. One treba da budu jasne, što jednostavnije i pregledne. Treba izbegavati vertikalne crte, a broj kolona ograničiti tako da tabela ne bi bila preširoka. Takođe, treba izbegavati nepotrebnu upotrebu horizontalnih crta. Naslov tabele, poravnat po levoj i desnoj margini, sa tačkom na kraju, navodi se sa jednim razmakom iznad tabele. Ispod tabele treba dati detaljno objašnjenje skraćenica, simbola i znakova korišćenih u samoj tabeli. Svaka tabela mora biti pomenuta u tekstu.

Ilustracije
Svi grafikoni, dijagrami i fotografije treba da se nazovu „Slika“ (1, 2, itd.). Prilažu se na odgovarajućem mestu u tekstu. Grafikone i dijagrame treba uraditi fontom 9, u crno-beloj tehnici i sa maksimalnom širinom od 13 cm. Voditi računa da oni budu čitki i jasni i nakon redukcije veličine. Za svaki grafikon i dijagram treba obezbediti detaljnu legendu bez skraćenica. Fotografije moraju biti visokog kvaliteta da bi se tehnički mogle dobro reprodukovati. Prilažu se u „TIF“ ili „JPG“ formatu, u crno-beloj tehnici. Naslov ilustracije, poravnat po levoj i desnoj margini, sa tačkom na kraju, navodi se sa jednim razmakom ispod ilustracije. Svaka ilustracija mora biti pomenuta u tekstu.

Skraćenice i jedinice
U radu treba koristiti samo standardne skraćenice. Merne jedinice treba izražavati u internacionalnom sistemu jedinica (SI). Kod navođenja jedinica posle broja treba da stoji razmak (osim za % i °C). Skraćenice se mogu koristiti i za druge izraze pod uslovom da se ti izrazi navedu u punom obliku prilikom prvog pominjanja, sa skraćenim oblikom u zagradi. Vrednosti od 1 do 9 mogu se izražavati slovima, a ostali brojevi isključivo numerički.

Nomenklatura
Celokupna nomenklatura (hemijska i biohemijska, taksonomska, genetička itd.) mora biti usklađena sa međunarodnim kodeksima i komisijama, kao što su *International Union of Pure and Applied Chemistry, IUPAC-IUB Combined Commission on Biochemical Nomenclature, Enzyme Nomenclature, International Code of Botanical Nomenclature, International Code of Nomenclature of Bacteria* itd.

Formule

Sve formule i jednačine u radu moraju biti urađene pomoću programa „Word Equation". Pri pisanju formula, radi preglednosti, ostaviti dovoljno praznog prostora oko same formule. Subskripti i superskripti treba da budu jasni. Prilikom pisanja jednačina treba dati smisao svih simbola odmah posle jednačine u kojoj se simbol prvi put koristi. Jednačine treba da budu numerisane arapskim brojevima, serijski u zagradama, na desnoj strani linije. Svaka jednačina mora biti pomenuta u tekstu kao Eq. (1), Eq. (2), itd.

Nakon objavljivanja rada, autoru za kontakt će biti poslat jedan primerak časopisa.
Mole se svi budući saradnici da rad pripreme prema datom uputstvu, kako bi olakšali rad redakcije časopisa. Ukoliko se rad ne pripremi po navedenom uputstvu neće biti prihvaćen za objavljivanje.

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