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Full Length Research Paper

Response of garlic (*Allium sativum* L.) to vermicompost and mineral N fertilizer application at Haramaya, Eastern Ethiopia

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Garlic (*Allium sativum* L.) is an important vegetable crop in Ethiopia. The yield of the crop is often constrained by low and unbalanced nutrient supply in the soil. This study was undertaken to assess response of garlic variety Chelenko I to vermicompost and mineral N fertilizer application on growth and bulb yield of the crop during the 2016/2017 main rainy season. The treatment consists of a factorial combination of four levels of vermicompost (0, 2.5, 5 and 7.5 t ha^{-1}) and five levels of mineral N fertilizer (0, 52.5, 80, 105 and 130 kg N ha^{-1}), laid out in a randomized complete block design in a factorial arrangement and replicated three times. Data was collected on plant growth, yield component and bulb yield of garlic. Results revealed that significant ($P < 0.05$) maximum leaf length (41.08 cm), bulb weight (39.17 g/bulb), harvest index (63.94%) and total bulb yield (12.93 t ha^{-1}) were recorded at the rate of 7.5 t ha^{-1} of vermicompost application while maximum average leaf width (1.25 cm), clove number (13.57 cm), and bulb dry matter (51.66%) were obtained at maximum rate of 130 kg ha^{-1} mineral N fertilizer. The results indicated that application of vermicompost at 7.5 t ha^{-1} and 130 kg Nha^{-1} mineral fertilizer gave the highest total garlic bulb yield of 12.9 and 12.69 t ha^{-1}, respectively.

Key words: *Chelenko* I, marketable bulb yield, response, total bulb yield, vermicompost.

INTRODUCTION

Garlic (*Allium sativum* L.) is primarily grown for its cloves, which are used mostly as food flavoring condiments due to groups of sulphur containing compounds: allin and allicin (Messiaen and Rouamba, 2004). Green tops are eaten fresh and cooked especially in tropical areas and consumption of immature bulbs for salad use is also popular (Block, 2010).

Despite its importance, in Ethiopia, imbalanced fertilizer use, lower soil fertility status in many soil types and lack of proper marketing facilities are among key production constraints (Getachew and Asfaw, 2000; Mohamed et al., 2014) which considerably reduce yield. Among the

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primary macronutrients, nitrogen (N), phosphorous (P) and potassium (K) are the most commonly reported deficient plant nutrients in most Ethiopian soils (Yohannes, 1994).

Crop nutrient requirements vary with species, variety, soil type and season, a blanket recommendation of 105 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1} each of N and P fertilizer are being used for garlic variety 'Tseday' production in many areas (EARO, 2004). This is also used for 'Chelenko I' (Tewdros et al., 2014) without research recommendation. This is one of the gaps addressed in the study area.

The traditional organic inputs such as crop residues, and animal manures cannot meet crop nutrient demand over large areas because of the limited quantities available, the low nutrient content of the materials, and the high labour demands for processing and application (Pratap et al., 2012). As interaction of organic and inorganic is valued, Verma et al. (2013) reported that the combined application of organic and inorganic fertilizers provided all the essential nutrients required by plants for its growth and development.

In addition, the application of bio-fertilizers like vermicompost (VC) has been recognized as an effective means for improving soil aggregation, structure and fertility, increasing microbial diversity and populations, improving the moisture-holding capacity of soils, increasing the soil cation exchange capacity (CEC) and increasing crop yields (Hargreaves et al., 2008).

An important feature of VC is that, during processing of the various organic wastes by earthworms, many of the nutrients that it contents are changed to forms that are more readily taken by plants such as nitrate or ammonium nitrate, exchangeable P and soluble K, Ca and Mg (Suthar and Singh, 2008). Therefore, complementary use of chemical fertilizers and organic manures has assumed great importance nowadays to maintain as well as sustain a higher level of soil fertility and crop productivity (Shalini et al., 2002).

In Ethiopia, garlic cultivation decreased from 16,411.19 ha, in 2013/14 to 15,381 ha in 2016/17 with a total production of 159,093.58 and 138,664.3 tons of bulbs with the productivity of 9.7 and 9.02 t ha^{-1}, respectively (CSA, 2017). Though the area covered by garlic, its production and productivity were not indicated in Eastern Hararghe, about 50,683 farmers produced local varieties of garlic. The yield of recently released garlic variety, 'Chelenko I', gave 9.3 t ha^{-1} on research field appreciated and selected for Eastern and Western Hararghe areas (Tewdros et al., 2014).

Varieties may also differ in their response to source and rate of applied fertilizers (Zhou et al., 2005). Moreover, no work has been done on effect of mineral N and VC on the performance of garlic in the area. Therefore, the study was initiated to assess the effect of VC and mineral N fertilizer on growth and bulb yield of garlic.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted at Haramaya University main campus, Rare research field during the main crop growing season, August to December 2016. The area is geographically located eastern part of the country at altitude of about 2006 m above sea level. The site has a bimodal rainfall distribution pattern and is representative of a sub-humid, mid-altitude agro-climatic zone. The mean annual rainfall is 790 mm (Belay et al., 1998; Simret et al., 2014) and the minimum and maximum temperatures are 3.8 and 25°C, respectively (Tekalign and Hammes, 2005). The soil of the experimental site is a well-drained deep alluvial with sandy loam texture (Simret et al., 2014).

Experimental materials, treatments and experimental design

Garlic variety '*Chelenko I* ' which was released in 2014 for mid to high altitude garlic growing areas of eastern and western Hararghe Zones by Haramaya University, was used. It is well adapted with productivity of 9.3 t ha^{-1} and moderately susceptible to garlic rust in Eastern Ethiopia. It takes about 132 days to mature (Tewodros et al., 2014).

The treatments consist of four rates of VC (0, 2.5, 5.0 and 7.5 t ha^{-1}), and five mineral N fertilizer rates (0, 52.5, 80, 105 and 130 kg N ha^{-1}); thus, the total treatments were 20. The experiment was laid out in randomized complete block design with three replications in a factorial combination.

Experimental procedures and crop management

Experimental field was ploughed by a tractor and plots were leveled and ridges of about 20 cm high were prepared. The gross plot size was 2.0 x 1.5 m (3.0 m^2). In between blocks and plots 0.75 m and 0.5 m space was left, respectively. VC was applied about two weeks before planting to randomly assigned treatments to each plot. One fourth, half and the remaining one fourth of the N fertilizer as per the treatment was also applied as urea at planting, and three weeks and six weeks after emergence of the garlic plants, respectively. In all the plots P (92 kg P_2O_5 ha^{-1}) was applied at planting through triple superphosphate. Healthy and uniform medium-sized cloves of 1.5 to 2.50 g (Fikreyohannes et al., 2008), were selected and planting was done on 11 August 2016 at the depth of 3 to 4 cm. The cloves were planted on the ridge at a spacing of 30 cm between rows and 10 cm between plants. Thus, there were five rows in each plot and 20 plants in a row. The outer most one row on each side of a plot and 20 cm on both ends of each row were considered as border. Thus, the net plot size was 0.9 x 1.8 m = 1.62 m^2. When 70% the plants showed neck fall (Getachew and Asfaw, 2000; EARO, 2004), harvesting of bulbs was done (on the 16^{th} of December 2016).

Vermicompost and soil sample analysis

Vermicompost sample, obtained made from *Lantana camara, Partinium hystrophorous* and farmyard manure, was analyzed before applying on the soil. Samples were taken randomly from the entire bag. It was broken into small crumbs and prepared for determination of chemical properties. The sample was air-dried and sieved through a 2 mm sieve. It's EC and pH was determined from the filtered suspension of 1:2.5 soils to water ratio using a glass electrode attached to a digital EC meter and pH meter. Sample was analyzed for electric conductivity (EC), total N, available P, exchangeable K, organic matter and organic carbon. Total N was determined using the Kjeldhal method (Jackson, 1958). Available P was determined by extraction with 0.5 M sodium bicarbonate ($NaHCO_3$) according to the methods of Olsen et al. (1954). Exchangeable K was determined with a flame photometer after extraction with 0.5 ammonium acetate according to Hesse (1971). Organic carbon of soil was determined by the Walkley-Black (1934) method.

In similar a way, soil sampling was done before planting. The samples were taken randomly using an auger in a zigzag pattern from the entire experimental field. Before planting, ten soil samples were taken from the top soil layer to a depth of 20 cm and composited in a bucket to represent the site. The soil was broken into small crumbs and thoroughly mixed. From this mixture, a composite sample weighing 1 kg was filled into a plastic bag. The chemical content of the soil was determined using similar procedures used for the VC as it was developed for the soil. Soil texture was determined by Bouyocous hydrometer method (Moodie et al., 1954).

Data collection and measurement

Growth parameters

Leaf width (cm): Leaf width of 10 individual leaves of the above selected plants was measured from the widest point of leaves and the average was taken as the leaf width.

Leaf length (cm): The length of the leaf from leaf sheath to the tip of the leaf was measured from 10 randomly taken plants and their average was expressed as leaf length.

Yield components and yield

Mean bulb weight (g): Ten bulbs were randomly taken from the net plot area and their weight was recorded by using sensitive balance. The average weight was expressed as bulb weight.

Clove number per bulb: The number of cloves was counted from the above 10 bulbs and their mean were taken as clove number per bulb.

Total bulb yield (t ha^{-1}): This was determined by weighing plants in the three central rows (sum of marketable and unmarketable bulbs) leaving the plants in both end of the row and weighed after curing at ambient condition using a sensitive balance and converted t ha^{-1}.

Bulb dry matter (%): The average dry matter weight (g) of bulbs after curing were measured by drying 10 randomly sampled bulbs in an oven with a forced hot air circulation at 70°C until a constant weight was obtained. The percent of bulb dry matter was calculated by taking the ratio of the dry weight to the fresh weight of the sampled bulbs and multiplying it by 100.

$$\text{BDM (\%)} = \frac{\text{Weight of bulb dry matter}}{\text{Bulb fresh weight}} \times 100$$

Harvest index (%): This was calculated as the ratio of bulb yield to biological yield (total weight of garlic plant including above and below ground yield) recorded from 10 plants sampled from the net plot area. This was computed by dividing mean weight of mature bulb of plants taken (economic yield) by the biomass yield of plants (biological yield) taken using the equation (Pessarakli, 2001):

$$\text{HI (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Data analysis

Data collected was subjected to analysis of variance (ANOVA) using SAS software version 9.0 and the means separated by using Turkey's Method at 0.05 level of significant if treatments are found significant.

RESULTS AND DISCUSSION

Physical and chemical properties of the soil

The result of laboratory analysis of selected physical and chemical properties of soils of the experimental area is presented in Table 1. The textural class of the soil was sandy clay loam based on the soil textural triangle of the International Society of Soil Science System (Moodie et al., 1954; Rowell, 1994). The pH of the experimental soil was 7.4 which is moderately alkaline on the basis of pH limit (7.4 to 7.8) according to Jones (2003). The pH is in the range of 6.5 to 7.5 favorable for garlic production (Bachmann, 2001). The OM of the experimental soil was 2.55%. According to Tekalign (1991), OM ranging from 0.86 to 2.59 is low, hence the soil might respond to the applied VC and mineral N fertilizers, as its organic matter content was low.

As per the rating (0.12 to 0.25%) described by Berhanu (1980), the total N content of the soil (0.18%) was medium. This value showed that the crop might respond to the applied VC and mineral N fertilizers (Table 1) due to increased soil fertility with application of both fertilizers. According to the rating (5 to 9 mg P kg^{-1}) suggested by Cottenie (1980), the available P of the soil was low (Table 1). This may be because of low percent of OM content of the soil (Table 1) which is also in agreement with the suggestion of Clark et al. (1998) who indicated that soil OM influences P availability to crops directly by contributing to P pool. However, Toung et al. (2000) reported that P response is likely in soils that have less than 20 mg kg^{-1} extractable P. The CEC of the experimental soil was 18.61 (cmol (+) kg^{-1}). This value was medium according to the rating (15 to 25) suggested by Landon (1991). This indicated that the soil of the experimental site might respond to the different VC and mineral N fertilizer. Hazelton and Murphy (2007) categorized exchangeable soil K contents of 0.3 to 0.7 Cmolc kg soil^{-1} as medium. In accordance with this category, the exchangeable soil K content of the experimental soil is in medium category. This indicates external application of mineral and/or organic fertilizers containing K is important for enhancing the fertility of the crop and yield of the crop.

Vermicompost analysis result

It is crucial to analysis nutrient contents of VC as it is soil activator, soil conditioner, and soil fertility booster with all required plant nutrient, vitamins, enzymes, growth

Table 1. Physical and chemical properties of the soil of the experimental site at Haramaya, Eastern Ethiopia.

Soil property	Value	Rating
Sand (%)	61	
Clay (%)	23	
Silt (%)	16	
Textural class	Sandy clay loam	
pH 1: 2.5 (H_2O)	7.4	Moderately alkaline
OC	1.48	Moderate
OM (%)	2.55	Low
Total N (%)	0.18	Medium/ moderate
Available P (mg kg^{-1})	5.58	Low
Exchangeable K (Cmolc kg^{-1})	0.32	Medium
CEC (cmol (+) kg^{-1})	18.61	Medium

OC, organic carbon; OM, organic matter.

Table 2. Chemical properties of vermicompost.

VC	Chemical properties						
	Total N (%)	Available P (ppm)	Exchangeable K [Cmol(+)/kg]	OM (%)	OC (%)	pH	EC (msm^{-1})
Value	0.56	25.82	23.69	15.39	8.92	7.25	8.83
Rating	Very high	Moderate	Very high	Very high	Very high	Neutral	Very high

OC, Organic carbon; OM, organic matter; VC, vermicompost; ppm, parts per million; EC, electric conductivity.

hormones and beneficial micro-organisms.

Chemical analysis of VC is given in Table 2. Its component is EC: 8.83 msm^{-1}, pH: 7.25, total N 0.56%, 25.82 ppm of available P, exchangeable K 23.69 Cmol(+)/kg VC, 15.39% of OM and OC 8.92% as indicated in Table 2. These VC increases soil fertility without polluting the soil, as well as the quantity and quality of crops. Moreover, beneficial effects of VC on plant growth under water deficit conditions may be due to better aeration to the plant roots, increasing amount of readily available water, induction of N, P and K exchange, thereby resulting in better growth of the plants. Application of bio-fertilizers such as VC have been recognized as an effective means for improving soil aggregation, structure and fertility, increasing microbial diversity and populations, improving the moisture-holding capacity of soils, increasing the soil cation exchange capacity and increasing crop yields. Municipal solid waste compost can also reduce the volume of the waste, kill pathogens that may be present, decrease germination of weeds in agricultural fields, and destroy malodorous compounds (Hargreaves et al., 2008).

Growth parameters

Leaf width

Analysis of variance showed that main effect of VC and mineral N fertilizer significantly ($P < 0.05$) affected leaf width but there was no significant observation due to their interactions. Application of 5 t VC ha^{-1} gave significantly optimum leaf width over the application rate of 2.5 t VC ha^{-1} and control, but statistically same with the application rate of 7.5 t VC ha^{-1} (Table 3). Verma et al. (2013) reported that chlorophyll contents of garlic leaf that contribute to leaf width increased significantly with application of 5 t VC ha^{-1}. Similarly, Mehdi et al. (2012) reported significantly increased leaf area index in response to the applied municipal solid waste and VC under well-watered, moderate and severe stress conditions. Abou El-Magd et al. (2012) also reported that the highest vegetative growth parameters were recorded with application of organic materials like poultry manure, farm-yard manure, sheep manure and compost.

N fertilization at the rate of 105 kg ha^{-1} gave significantly optimum higher leaf width over the other low N rates and statistically at par with application of 130 kg ha^{-1} (Table 3). As N increased from 0 to 105, leaf widths was increased by 15%. Adequate application of N plays an important role in the production of vigorous vegetative and optimum leaf expansion of garlic and influences garlic bulb size produced (Stork et al., 2004). Kakar et al. (2002) reported that N fertilization is necessary for ensuring successful vegetative growth of garlic. Similarly, Tadesse (2015) also reported that application of N significantly increased leaf width in comparison with lower

Table 3. Main effects of vermicompost and N on leaf width and leaf length of garlic.

Factor	Treatment	Leaf width (cm)	Leaf length (cm)
	0	1.09[c]	34.55[c]
	2.5	1.18[b]	37.17[b]
VC (t ha^{-1})	5	1.20[ab]	38.44[b]
	7.5	1.23[a]	41.08[a]
LSD (0.05)		0.05	1.81
	0	1.08[c]	34.56[d]
	52.5	1.16[b]	36.70[dc]
N (kg ha^{-1})	80	1.20[ab]	38.31[bc]
	105	1.23[a]	39.63[ab]
	130	1.25[a]	40.94a
LSD (0.05)		0.06	2.16
CV %		4.80	4.86

Means followed by the same letter within a column are not significantly different at 5% level of significance.

dose and nil application of N fertilizer. The result revealed that leaf width increase with increased levels of fertilizers is directly proportion to leaf area index.

Leaf length

Analysis of variance indicated that the main effect of VC and N fertilization rate showed significant differences ($p < 0.05$) on leaf length but their interaction did not.

As shown in Table 3, the average maximum leaf length was found at the maximum rate of application of VC (7.5 t ha^{-1}) which was significantly superior to rest of the treatments. Nil application of VC gave significant minimum leaf length and leaf length increased by 18.90% with the application of 7.5 t VC ha^{-1} as compared to nil VC application (Table 3). This increase in the vegetative growth might also be due to the effect of nutrients which are exerted by bio-enriched (Gomaa, 1995). This result is also in line with that of Mehdi et al. (2012) who reported significantly increased leaf area index in response to the applied municipal solid waste and VC under well-watered, moderate and severe stress conditions.

The analysis of variance indicated that N significantly affected leaf length. Optimum leaf length was recorded with application of 105 kg N ha^{-1}. Application of N at rate of 105 kg ha^{-1} increased leaf length by about 14.67% as compared to untreated plot (Table 3). The increase in leaf length in response to the increased rate of N application may be attributed to the positive effect of N on vegetative growth and leaf expansion as suggested by Marschner (1995) and Halvin et al. (2003).

Similarly, Betewulign and Solomon (2014) reported that leaf length of garlic increased with increased rate of mineral N fertilizer. Kakar et al. (2002) also reported that N accounts for a higher percentage of the variation in leaf area when it was increased from 50 to 200 kg ha^{-1}. The leaf area is due to increased leaf length and width. Dirba et al. (2013) found that leaf area index of garlic treated with different levels of fertilizers was significantly increased over the untreated (control) plot at all sampling growth stages.

Yield components and yield

Bulb weight and clove number per bulb

Significant variations ($p < 0.05$) were obtained among bulb weights and clove number per bulb due to the main effect of VC and N application rate. However, their interaction had no significant influence on them (Table 4).

Significant maximum mean bulb weight was obtained from plots treated with VC at the rate 7.5 t ha^{-1} as compared to the rest treatments. The maximum VC application rate gave 29.23% increase in bulb weight over the nil VC received plots (Table 4). The increase in mean bulb weight in response to increase in the rate of VC may be ascribed to several growth promoters, enzymes, beneficial bacteria and mycorrhyzae contained in it that led to high mean bulb weight by facilitating improved leaf growth and photosynthetic activities; thereby, increasing portioning of assimilate to the storage organ (Gupta, 2005). Alemu et al. (2016) reported that application of VC at the rate of 5 t ha^{-1} increased mean bulb weight by 8% as compared to the control plots. Weight of the bulb increased significantly up to the highest dose of 7.5 t VC ha^{-1} (Verma et al., 2013).

Application of highest level of mineral N fertilizer rate produced significantly increased bulb weight by 25.47% over the control. The increase in mean fresh bulb weight in response to N application could be attributed to the increase in number of leaves produced, leaf length, and extended physiological maturity in response to the

Table 4. Main effects of application vermicompost and N on bulb weight and clove number per bulb of garlic.

Factor	Treatment	Bulb weight (g/p)	Clove number per bulb
VC (t ha^{-1})	0	30.31^{d}	12.35^{b}
	2.5	32.73^{c}	12.98^{a}
	5	36.33^{b}	13.07^{a}
	7.5	39.17^{a}	13.22^{a}
LSD (0.05)		1.77	0.47
N (Kg ha^{-1})	0	30.68^{d}	12.41^{c}
	52.5	32.26^{cd}	12.59^{c}
	80	33.51^{c}	12.76^{bc}
	105	35.78^{b}	13.19^{ab}
	130	38.43^{a}	13.57^{a}
LS (0.05)		2.12	0.57
CV %		5.31	3.78

g/p, gram per plant. Means followed by the same letter within a column are not significantly different at 5% level of significance.

fertilization, all of which may have led to increased assimilate production and allocation to the bulbs (Kokobe et al., 2013). According to Bhagwan et al. (2012), successive levels of N fertilizers significantly increased the weight of garlic bulb. Besides, Tadesse (2015) also observed that the application of N significantly increased weight of bulb in comparison with lower dose and nil application of N fertilizer.

Results indicated in Table 4 for clove number per bulb, VC application at the rate of 2.5, 5 and 7.5 t ha^{-1} showed significantly increased garlic cloves number per bulb over the control. Statistically, these three levels were not different. Agarwal (1999) reported that VC is a nutritive organic fertilizer rich in macronutrients, micronutrients, beneficial soil microbes like N-fixing bacteria and mycorrhizal fungi. Additionally, VC contain enzymes like amylase, lipase, cellulase and chitinase, which continue to break down organic matter in the soil (to release the nutrients and make it available to the plant roots) even after they have been excreted (Gupta, 2005). Clove number of garlic increased significantly up to 5 t ha^{-1} of VC (Verma et al., 2013). Surindra (2009) found that integrated nutrient supply in the form of traditional inorganic NPK and in the form of organic manures brings an excellent biochemical changes in soil structure, which ultimately promotes plant growth and production. Alemu et al. (2016) also reported that application of VC showed significant difference in mean clove number.

Analysis of variance showed that application of 105 kg ha^{-1} mineral N fertilizer gave optimum clove number per bulb. This might be due to the fact N is a constituent of many fundamental cell components and plays a vital role in all living tissues of the plant. This result is in line with the result of Bhagwan et al. (2012) who reported that successive levels of fertilizers significantly increased the number of cloves per bulb. According to Zaman et al. (2011) and Hossein et al. (2014), the highest number of cloves per bulb was obtained from 150 and 125 kg N ha^{-1}, respectively and the lowest was found in the control treatments.

Harvest index

The main effect of VC and N significantly ($p < 0.05$) influenced harvest index of garlic. The interaction effect of VC and mineral N fertilizer did not show significant effect on harvest index.

Significant maximum harvest index (63.94%) was recorded at the rate of 7.5 t VC ha^{-1} application over the other rate of application and followed by 5 t VC ha^{-1} application rate (Table 5). There was consistent increase in percent of harvest index. This could be attributed to the strong movement of assimilates from the leaves to the bulbs during the growing period. An important feature of VC is that, during the processing of the various organic wastes by earthworms, many of the nutrients that it contains are changed to forms that are more readily taken by plants such as nitrate or ammonium nitrate, exchangeable P and soluble K, calcium and magnesium (Suthar and Singh, 2008). Alemu et al. (2016) reported that VC had no significant effect on harvest index.

Application of 130 kg N ha^{-1} N gave significantly highest harvest index (60.52%) over other rates of mineral N fertilizer except 105 kg N ha^{-1}. Significantly lowest percent harvest index (51.82) was obtained from plots that did not receive N fertilization followed by 55.87 percent harvest index obtained from 52.5 kg N ha^{-1} application. N application at the rate of 52.5 kg ha^{-1} had significantly higher percent harvest index from nil application of N but was not significantly different as compared to the application rate of 80 kg N ha^{-1} (Table 5). The observed improvement in harvest index could be attributed to enhanced production of photosynthate due

Table 5. Main effects of vermicompost and N on percent harvest index, bulb dry matter and total bulb yield of garlic.

Factor	Treatments	Harvest index (%)	Bulb dry matter (%)	Total bulb yield (t ha^{-1})
VC (t ha^{-1})	0	51.76^{d}	47.12^{c}	9.32^{d}
	2.5	55.42^{c}	48.44^{b}	10.80^{c}
	5	59.96^{b}	49.37^{ab}	12.00^{b}
	7.5	63.94^{a}	49.88^{a}	12.93^{a}
LSD (0.05)		2.08	0.97	0.58
N(kg ha^{-1})	0	51.82^{d}	46.10^{c}	10.12^{d}
	52.5	55.87^{c}	46.88^{c}	10.64^{cd}
	80	57.04^{bc}	48.21^{b}	11.06^{c}
	105	58.92^{ab}	50.72^{a}	11.82^{b}
	130	60.52^{a}	51.66^{a}	12.69^{a}
LSD (0.05)		2.48	1.16	0.69
CV %		3.69	2.05	5.21

Means followed by the same letter within a column are not significantly different at 5% level of significance.

to increased leaf area, hence, greater partitioning of the photosynthate to the bulbs.

The finding of Dargie (2015) showed that increased rate of N fertilizer from 0 to 64 kg ha^{-1} increased harvest index of onion by about 5.0%. This shows that mineral N fertilizer contributed to increase in harvest index.

Bulb dry matter

Significant increase in percent dry matter content of garlic bulbs were recorded due to main effect of VC and N fertilizers applied ($p < 0.05$). However, bulb dry matter percent was not significantly affected by their interaction effects.

Bulb dry matter percent was increased by 5.86% due to increased level of VC rate from 0 to 7.5 t ha^{-1}. Optimum bulb dry mater percent was obtained from the application rate of 5 t VC ha^{-1} which was significantly not different from the application of 5 t VC ha^{-1} (Table 5). Juan et al. (2006) showed that application VC increased the bulb dry weight due to the accumulation of non-structural carbohydrates whose distribution patterns change, thus favouring the metabolism of fructan precursors and accumulating as scorodose. The authors further explained that reserve substance (scorodose) accumulation in the VC treatment represented by scorodose polysaccharide, occurs for a longer period due to the earlier start of bulbing. This response translates into a 2-fold increase of the bulbs dry weight, increased size and therefore, higher quality and yield at harvest. Similarly, Fenwik and Hanley (1985) reported that, in garlic, the fructan polysaccharide is the scorode which accounts for 53% of garlic dry matter.

Application of 105 kg N ha^{-1} which was 50.72% dry matter, did not differ significantly from the application of 7.5 t VC ha^{-1} but significantly differ from the others low application rates. N application at the rate of 130 kg N ha^{-1} gave significantly highest dry matter percent (51.66%) over the nil application, 52.5 and 80 kg N ha^{-1}. Hence, the application 130 kg N ha^{-1} gave 12.06% increase in bulb dry matter when compared with the control.

Hassan (2015) elaborated that increase of plant growth that contribute to bulb dry weight by increasing N level might be due to its role in photosynthesis, protein synthesis, cell division and enlargement which are the basal steps of plant growth. In addition, N plays an important role in the enzyme activity which reflects more products needed in plant growth. The author indicated that as N level increased, dry weight per plant increased up to the highest N level. Kakar et al. (2002) reported that N accounts for a higher percentage of the variation in dry plant mass when it was increased from 50 to 200 kg ha^{-1}. Alemu et al. (2016) also figured out that bulb dry matter percent was increased by 14.21% due to increased level of N rate from 0 to 46 kg ha^{-1}. Increasing rate of N application from nil to 130 kg N ha^{-1} bulb dry matter was increased by 12.06%.

Total bulb yield

Yield is a complex parameter that results from the interaction of various yield contributing characters. The maximum total bulb yield (12.93 t ha^{-1}) was recorded with application of 7.5 t VC ha^{-1} which was statistically different from the rest of the treatments (Table 5).

As indicated in Table 5, there was an increase of 38.73% in total bulb yield by application of VC at rate of 7.5 t ha^{-1} over control. This might be due to the fact that organic manure supplied to balanced nutrition to the crop, improved soil condition; thereby, resulting in better growth and development leading to higher yield attributes and yield. Pramanik et al. (2007) found that humic acids released from VC enhanced nutrient uptake by the plants by increasing the permeability of root cell membrane, and stimulating root growth.

Plots that received mineral N fertilizer at the rate of 130 kg ha^{-1} increased by 25.40% in yield as compared to the control or nil application of N. Mineral N fertilizer application at the rate of 130 kg N ha^{-1} resulted in significantly maximum total bulb yield (12.69 t ha^{-1}) followed by 105 kg N ha^{-1} application rate which gave 11.82 t ha^{-1}. The least bulb yield was recorded from nil application of fertilizers (Table 5). This result suggests that N application to the soil is important to improve bulb yield of garlic significantly. This might be due to the fact that N is a major part of all amino acids that increases the vegetative growth and produces good quality foliage and promotes carbohydrate synthesis through photosynthesis and ultimately increased yield of plants.

Bulb crops are a heavy feeder, requiring optimum supplies of N, P, K and S and other nutrients which can adversely affect growth, yield and quality of bulbs under suboptimal levels in the soil (Gubb and Tavis, 2002). According to Bhagwan et al. (2012) successive levels of fertilizers significantly increased the weight of bulb, number of cloves per bulb and bulb yield. The authors reported that maximum bulb yield (13.86 t ha^{-1}) was obtained with application of 100% recommended dose of fertilizer, which is 41.7% higher than the control. Singh and Singh (2006) and Kokebe et al. (2013) also reported that increase in the rate of N from 0 to 100 kg N ha^{-1} resulted in progressive increments in total bulb yield of onion.

Conclusions

Research was conducted to study the response of garlic to VC and mineral N fertilizer application rates with the objectives of assessing the effect of VC and mineral N fertilizer on growth and bulb yield of garlic. Growth parameters such as leaf width and leaf length were significantly influenced by the applied VC and N fertilizers. The highest leaf width (1.25.cm) and leaf length (41.08 cm) were recorded for 7.5 t VC ha^{-1} and 130 kg N ha^{-1}, respectively.

Yield components and yield traits showed significant differences ($p < 0.05$) in response to the application of VC and mineral N fertilizer. Maximum bulb weight (39.17 g/plant), harvest index (63.94%) and total bulb yield (12.93 t ha^{-1}) were recorded from the application rate of 7.5 t VC ha^{-1}. The highest clove number (13.57) and bulb dry matter (51.66%) were recorded from highest rate of 130 kg N ha^{-1}. Significantly highest total bulb yield, 12.93 and 12.69 t ha^{-1}, was obtained from maximum application rate of 7.5 t VC ha^{-1} and 130 kg N ha^{-1} mineral fertilizer, respectively.

Thus, it can be reasonably generalized that on short term basis, application of high amounts of VC fertilizers can result in highest total bulb yield than other low doses of either VC and mineral N fertilizer or their combination. Therefore, from the results of this study, it can be concluded that, the maximum total bulb yield of garlic was obtained with the application of 7.5 t VC ha^{-1} fertilizer as it also has positive impacts on soil biological, aggregation and chemical condition.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Performance of maize hybrids under different tillage methods and nitrogen levels

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A field experiment was conducted at the National Maize Research Program (NMRP), Chitwan, Nepal during summer of 2014 to evaluate the response of tillage methods (conventional and zero tillage) and nitrogen levels (0, 60, 120 and 180 kg ha^{-1}) on grain yield of two maize (*Zea mays* L.) hybrids (Rampur hybrid-2 and RML32/RML17). The experiment was laid out in strip-split plot design consisting of sixteen treatments with three replications. Growth and yield parameters of maize were measured and economic analysis was conducted during plant growth and after harvest. The maize hybrids, Rampur hybrid-2 and RML32/RML17, and tillage methods, zero tillage and conventional tillage, had similar grain yield (2.9 t ha^{-1}). The grain yield obtained from control without nitrogen application (1.64 t ha^{-1}) was significantly lower than that of all levels (60, 120 and 180 kg ha^{-1}) of nitrogen. The grain yield (3.57 t ha^{-1}) obtained with 180 kg N ha^{-1} was significantly higher than 60 kg N ha^{-1} (3.05 t ha^{-1}) but was at par with 120 kg N ha^{-1} (3.44 t ha^{-1}). The difference between 120 and 60 kg N ha^{-1} application with respect to grain yield was non-significant. Grain yield increased non-linearly with increasing levels of N application, while the physical and economical maximum doses of nitrogen equaled to 172.38 and 153.77 for zero tillage, and 140.00 and 127.86 kg ha^{-1} for conventional tillage methods, respectively. Results highlight the potential use of zero tillage with 120 kg ha^{-1} nitrogen level in hybrid varieties to harness agronomic and economic benefits in the inner Terai region of Nepal during summer season.

Key words: Maize hybrids, tillage, nitrogen, yield.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops next to wheat and rice in the world (Rawal and Kuligod, 2014). Globally, maize is cultivated in nearly 177 million ha, producing 960 million metric tons (FAOSTAT, 2013). In Nepal, maize shares about 24% of the total cereal production, and is the most important staple food crop of hilly region and placed second after rice (MOAD, 2013). It shares about 6.54% to Agricultural Gross Domestic Product (AGDP). Maize is grown in approximately 0.85 million ha with annual total production of 1.9 million metric tons and productivity of 2.35 t ha^{-1} (MOAD, 2013). While grain yield of hybrid maize may

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range between 5 and 9 during winter (Bishwokarma et al., 2015), information on yield of such improved varieties during summer season is incomplete. The average yield per hectare in Nepal (2.35 t ha^{-1}) is still very low despite suitable production environment and high yielding varieties. Different factors such as genotypes, tillage, nitrogen levels, and climate (temperature and precipitation) influence remarkably on the growth and grain yield of maize among others crops (Paudel et al., 2014). The need of the grain maize is increasing in the hills of Nepal for human consumption as staple food and for livestock feed in Terai and inner Terai (Pandey et al., 2007). Thus, hybrid maize can be a good option to increase the total production of maize grains with high input in Terai and mid-hills. It is because of the fact that the hybrid maize gives significantly higher grain yield than the open pollinated varieties (Shah et al., 2014).

Maize cultivation is subjected to tillage operation at different growth stages to facilitate germination of seed and promote plant growth and development. In conventional tillage, the soil is opened with mouldboard plough for primary tillage. The soil mass is broken into a loose system of colds of mixes sizes. Subsequently, a fine seedbed is prepared by secondary tillage (Ghimire et al., 2016). Zero tillage is an extreme form of minimum tillage. Primary tillage is completely avoided and secondary tillage is restricted to seed bed preparation in the row zone only. Zero tillage is advantageous where soils are subjected to wind and water erosion, tillage operation is too difficult and labor for tillage are too high (Ghimire et al., 2016). Khurshid et al. (2006) reported that tillage contributes up to 20% of the crop production factors. Recently, conservation tillage practices such as zero and minimum tillage are emphasized for soil water conservation, fuel energy saving, and erosion control (Sharafi et al., 2013). Thus, with scientific basis, zero-tillage as an alternative to conventional tillage is gaining popularity worldwide (Monneveux et al., 2006).

Soil is important for plant survival, balancing environment, ecology and climate. Maize is heavy feeder of nutrients. Nitrogen (N) has been considered as a primary nutrient in the fertilizer management programme to obtain the yield potential of maize crop (Sampath et al., 2013). A study conducted in Hyderabad, India, reported that N fertilization at 100 kg ha^{-1} increased grain yield from 43 to 68% and above ground biomass production from 25 to 42% as compared to 0 kg N ha^{-1} (Ogola et al., 2002). Further, it is assumed that for every 100 kg of grain yield, 1.8 kg N in the grain and 1.0 kg in the above ground parts of the plant are required and must be supplied by soil and/or fertilizer (Sampath et al., 2013). It has been reported that agronomic managements like proper tillage (Duiker et al., 2006) and fertilizer application (Rasheed et al., 2004) increased yield attributes and ultimately the grain yield. However, there is limited understanding on the response of hybrid maize to different level of nitrogenous fertilizers under different tillage practices in Terai region of Nepal. Moreover, the economic level of fertilizer application maize production is rarely evaluated. The objective of this research was to evaluate the response of different maize hybrids to nitrogen levels under different tillage systems for maximizing grain yields during summer season in 2014 at NMRP, Rampur.

MATERIALS AND METHODS

Experimental site

The experiment was conducted during summer season (May to September) of 2014 at the research farm of National Maize Research Program (NMRP), Rampur, Chitwan, Nepal. The experimental site is located 10 km south-west direction from district headquarter of Chitwan district, Nepal. It is located at 27°37' North latitude and 84° 25' East longitude with an elevation of 256 m above mean sea level. Geographically, the experimental location falls in the inner Terai region of central development region of Nepal. Total rainfall received during the experiment was 1936.35 mm and the mean maximum and minimum temperature was 36.87 and 19.5°C, respectively.

Soil samples were collected from 0 to 15 cm soil depths of experimental plots and total nitrogen was determined by the Macro-Kjeldahl method, available phosphorus by the Olsen's bicarbonate method, available potassium by the ammonium acetate method and organic matter was determined by the Walkley and Black method in Central Soil Science Laboratory of Nepal Agriculture Research Council (NARC), Khumaltar (Khanal et al., 2014).

From soil analysis, sand (71.5%) was found dominant soil particle followed by silt (18.5%) and clay (11%), which signify sandy loam texture of the experimental soil. Furthermore, the total nitrogen, available phosphorus and available potassium were 0.165%, 34.38 kg ha^{-1}, and 73.89 kg ha^{-1} in the top soil layer, respectively. Similarly, soil organic matter content was 3.12%. Soil pH was found to be acidic (5.39).

Experimental design, tillage and fertilization

The experiment was laid out in strip split plot design with sixteen treatments and three replications by assigning two maize hybrids (Rampur hybrid-2 and RML 32/RML 17) as horizontal factor, two tillage systems (Zero and conventional tillage) as vertical factor and four levels of nitrogen (0, 60, 120 and 180 kg N ha^{-1}) as sub plot factor.

Thus, altogether there were 8 rows in each plot of which 1st and 8th rows were treated as boarder rows. The central three rows (5, 6 and 7th) were used as net plot rows for harvesting and remaining rows (2, 3 and 4) were treated for biometrical and phenological observations.

The individual gross plot size was 30 m^2 consisting of 5 m length and 6 m breadth. Row to row spacing was maintained at 75 cm and plant to plant at 25 cm for each plot. The net experimental area was 1516 m^2 consisting of 48 plots (Figure 1). The experimental plots for conventional tillage were prepared by ploughing the plots with tractor 15 days prior to sowing seeds. For zero tillage, the field was sprayed with glyphosate 47/VL using recommended dose (5 ml/L of water) to make field free from weeds.

In the experimental field, farm yard manure (FYM) at the rate of 10 t ha^{-1} was applied as a main source of organic fertilizer. Maize was fertilized with 120:60:40 NPK kg ha^{-1}. The required amount of nitrogen fertilizer was calculated separately for each treatment. The total nitrogen at 0, 130, 260.85 and 391.2 g per plot were applied in

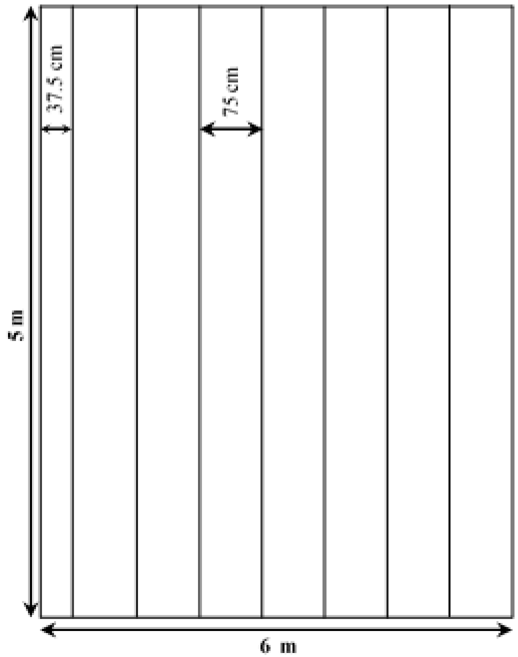

Figure 1. Plot design. 1st and 8th rows = boarder row; 2nd row = destructive row; 3rd row = guard row for 4, 5, 6, and 7th row; 4th row = plant height; 5, 6, and 7th row = net rows.

the study that corresponds to the application of 0, 60, 120 and 180 kg N ha^{-1}. Urea was used as a source of nitrogen and applied in three splits; at sowing, knee height and tasseling stages. The plots which had 0 kg N ha^{-1} treatment received 1.125 g phosphorus and 200 g potassium per plot through single super phosphate (SSP) and muriate of potash (MOP). The amount of diammonium phosphate used was 390 g per plot for the plots receiving the 60, 120 and 180 kg N ha^{-1}.

Atrazine was used, 1.25 kg ha^{-1} of active ingredient one day after sowing to suppress the weeds. For control of cut worm, Cypermethrin at 2 ml/L of water was sprayed on 30 days after sowing (DAS). Harvesting was done on 22nd September 2014, from net plot consisting of 3 rows (5th, 6th and 7th rows) and converted into yield per hectare.

Observation and measurement

Grain yield

Grain yield was calculated from net plot. Cobs were dried, threshed, cleaned and dried again to bring moisture to as low as 15%. Then final weight was recorded.

Grain yield (t ha^{-1}) = Field ear weight × Shelling % × (100-GMC %) ×10 / Net harvest area × 85

where GMC is the grain moisture content.

Stover yield

All maize plants in the net plots were harvested from the base near the soil surface and weighed.

Harvest index

Harvest index is the ratio of grain yield and total upper ground biomass which indicates the efficiency of plant to assimilate partition to the parts of economic yield (that is, maize grain) (Bishwokarma and Shrestha, 2014). Harvest index in percentage was calculated following the method described by Beadle (1987).

Harvest index = [Economical yield (grain yield, kg ha^{-1}) / Biological yield (grain + stover yield, kg ha^{-1})] × 100

Statistical analysis

Data were tested for normality and constant variance and the relationship between nitrogen level and grain yield was analyzed using non-linear regression analyses using MSTAT-C package. Data were subjected to Analysis of Variance (ANOVA) to evaluate the effect of hybrid varieties, tillage methods and nitrogen levels, and their interaction on grain yield (t ha^{-1}), stover yield (t ha^{-1}) and harvest index of maize. Duncan Multiple Range Test (DMRT) was used to compare means using Least Significance Difference (LSD) at 5% level of significance (Khanal et al., 2014; Shrestha et al., 2013).

RESULTS AND DISCUSSION

Grain yield

Rampur hybrid-2 and RML32/RML17 hybrids showed similar performance in respect of grain yield formation (2.93 and 2.9 t ha^{-1}, respectively). Results showed no significant effect of the tillage methods on grain yields of hybrid maize in the humid subtropical climate of Chitwan, Nepal. The grain yield from control treatment without nitrogen application (1.64 t ha^{-1}) was significantly lower than that of all levels (60, 120 and 180 kg ha^{-1}) of nitrogen (3.05, 3.44 and 3.57 t ha^{-1}, respectively, $P < 0.05$). Application of nitrogen at 60, 120 and 180 kg ha^{-1} increased grain yield significantly as compared to control indicating the need of nitrogen fertilizer for boosting maize productivity in sandy loam soil of Chitwan. This is in agreement with Mosis et al. (2007) and Wonde et al. (2007) who reported that application of nitrogen increases grain yield of hybrid maize varieties under optimum condition of nitrogen level. Similarly, Khaliq et al. (2009) and Ahmad et al. (2009) suggested that the grain yield increases by increasing the nitrogen level. Soil fertility acts as a yield-limiting factor in maize production under excessive leaching of soil nitrogen during rainy season (Bekeko, 2013). The grain yield obtained with 180 kg N ha^{-1} was at par with that of 120 kg N ha^{-1} but significantly higher than 60 kg N ha^{-1}. Effect of nitrogen levels on grain yield was significant and grain yield increased non-linearly with increasing N levels. The physical and economical maximum doses of nitrogen were higher for RML32/RML17 in conventional tillage compared with zero tillage. Surprisingly, economical maximum doses of nitrogen were higher in zero tillage compared with conventional tillage for Rampur hybrid-2 compared to RML32/RML17. Reason behind difference in physical and economical maximum doses of two hybrids in different tillage system is unknown as these hybrids are launched recently and studies regarding these hybrids in different tillage and nitrogen levels are not available.

In the current study, yield from two hybrid varieties grown during the summer 2014 were similar to each other in respect of grain yield formation. This indicates that the varieties did not differ in their genetic make-up or potential and capacity to transport photosynthates from source to sink. Other studies with hybrid maize in South and South-West Asian countries show similar results (Mukhtar et al., 2011; Muhammad et al., 2004; Wajid et al., 2007). For example, Mukhtar et al. (2011) tested two maize hybrids (YH-1898 and YH-1921) with different nitrogen level and reported grain yield of 6.734 and 7.622 t ha^{-1}. The yield reported in their studies with other hybrid maize were higher compared with the current study. The present experiment was done during the monsoon season of Nepal, which is characterized by greater rainfall and cloudy days during the growing season. Heavy rain likely leached applied nitrogen, and cloudy weather potentially affected photosynthesis process resulting poor grain yield. Depletion of organic matter and fertility in tilled plots could be the reason for getting similar grain yield in conventional tillage compared to zero tillage (Shah et al., 2014; Ghimire et al., 2016). In the present research the values of weed dry matter recorded in zero and conventional tillage methods were similar to each other at all growth stages (22, 55 and 75 DAS). Similar results were obtained by Chopra et al. (2007) during 30 and 90 DAS and at harvest. This might be causal factor for obtaining similar effects of tillage practices on grain yield of hybrid maize varieties.

Stover yield

The stover yield produced by Rampur hybrid-2 (4.97 t ha^{-1}) was significantly higher than that of RML32/RML17 (4.49 t ha^{-1}). No difference in stover yield between different hybrids (Gaurav and Rajkumar) was also reported by Dawadi and Sah (2012) on a study conducted in the same research station. In the current study, stover yield was not significantly influenced by tillage methods (zero tillage 4.62 t ha^{-1}; conventional tillage 4.84 t ha^{-1}). These results are inconsistent with the results obtained by Chopra and Angiras (2007) in which they reported significantly higher stover yield in conventional tillage compared with zero tillage using maize variety PSCL-3438 during Kharif season at Himanchal Pradesh in India. Differences in hybrids, season of the year and eco-region for maize cultivation are likely to result in different stover yield. Significantly higher stover yield was obtained in the treatment with 180 kg nitrogen (6.44 t ha^{-1}) per hectare in comparison to control (2.71 t ha^{-1}), 60 (4.21 t ha^{-1}), but remained at par with 120 (5.65 t ha^{-1}) kg N ha^{-1}. Other studies also indicate increase in stover yield with increased level of nitrogen (Dawadi and Sah, 2012; Sampath et al., 2014). In the current study, there was no interaction between hybrid, tillage methods and nitrogen levels with respect to stover yield.

Physical maximum vs. economic maximum

The effect of nitrogen levels on grain yield of maize hybrid was significant ($P < 0.05$) and polynomial regression equation was obtained. The values of coefficient of determination (R^2) shows contribution of nitrogen in the formation of grain yield was remarkably higher in case of RML32/RML17 (73 and 85%) as compared to Rampur hybrid-2 (61 and 54%) under zero and conventional tillage practices, respectively. Further, the relationships between nitrogen levels and grain yield were found strong as indicated by the values of correlation coefficient (r) which were remarkably higher for RML32/RML17 (0.857 and 0.921) than Rampur hybrid-2 (0.786 and 0.738) under zero and conventional tillage practices, respectively. Moreover, the physical and economical maximum doses indicate that they were higher for RML32/RML17 in conventional tillage but lower in zero tillage as compared to Rampur hybrid-2 and vice-versa for Rampur hybrid-2. The average value of these parameters showed that they were remarkably higher in zero tillage (172.38 and 153.77 kg N ha^{-1}) as compared to conventional tillage (140.00 and 127.86 kg N ha^{-1}), respectively. The results from the finding are consistent with Randall and Bandle (1991) who reported that in the fertilizer N rates are increased up to 25% to counter the adverse effect on yield from sort term immobilization in zero tillage. It is because of the fact that the estimates of the lower N in zero tillage vary from 10 to 40 kg ha^{-1} in comparison to tilled soils (Bandel et al., 1984).

Thus, on the basis of the aforementioned analysis it can be mentioned that N is a vital plant nutrient and major yield determining factor in maize production (Shanti et al., 1997).

Harvest index (HI)

The maize hybrids did not significantly influence harvest index (RML32/RML17, 0.37; Rampur hybrid-2, 0.34). To our understanding, this is the first study to report the effect of RML 32/RML17 and Rampur hybrid-2 maize on harvest index. Studies from other maize hybrids indicate differences in harvest index (Wajid et al., 2007). In this study, tillage methods had no significant effect on harvest index (zero tillage, 0.35; conventional tillage, 0.36) which is consistent with results from Chopra and Angiras (2007) and Pandey and Chaudhary (2014). The largest harvest index was obtained from 60 kg ha^{-1}N (0.404) but the index did not differ significantly between 180 (0.43), 0 (0.32) and 120 (0.362) kg N ha^{-1} application. The effect of nitrogen level in harvest index is consistent with Dawadi and Sah (2012) but inconsistent with Pandey and Chaudhary (2014). Such difference in the result could be due to difference in maize hybrids and season of growth.

Conclusion

This study clearly demonstrates the dependency of grain yield in Terai, Nepal on N application. Grain yield was not significantly influenced by hybrids and tillage methods. However, grain yield increased continuously with the increasing nitrogen level. The grain yield from 180 kg ha^{-1} was at par with 120 kg ha^{-1} which indicates that higher rate of nitrogen application is not sound strategy to obtain maximum grain yield. This study outlines 120 kg N ha^{-1} as an appropriate dose N fertilization for hybrids maize cultivation in inner Terai region of Nepal. However, more research is warranted for better understanding of the influence of tillage practices and nitrogen levels on yield sustainability in maize cultivation across different climate and agro-ecological regions.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Effects of growth media on rooting of stem cuttings of hybrid coffee varieties

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The objective of this study was to evaluate the effect of different growth media on rooting of stem cuttings of hybrid coffee varieties. The experiment was conducted on-station under a shade house at Tanzania Coffee Research Institute (TaCRI) from October 2013 to February 2014 using a split plot experiment in a Randomized Complete Block Design (RCBD) with four replications. The main factor consisted of five hybrid coffee varieties (KP423-1, KP423-2, N39-3, N39-2 and N39-7) and the sub-factor consisted of five types of rooting media (red soil, peat moss, decomposed saw dust, rice husk and forest soil + fine sand 2:1 (v/v) as a control). The stem cuttings were planted in each type of the media and four months after planting, the cuttings were evaluated based on number of rooted cuttings, total number of roots per cutting, number of lateral roots per cutting and root length. The data were subjected to analysis of variance using CoStat software and treatment means were separated based on Tukey's test at P ≤ 0.05. Results indicate that coffee varieties N39-2 and N39-3 produced the highest rooted stem cuttings of 64.2 and 63.9% respectively. Results also show that red soil media provided the highest rooted stem cuttings of 77.9% followed by sawdust with 68.0%. It is recommended that propagators should use red soil as a rooting media for improving rooting percentage of stem cuttings from improved coffee varieties. Further studies are required to improve chemical and physical properties of red soil media.

Key words: Hybrid coffee, mass multiplication, propagation, rooting media, stem cuttings.

INTRODUCTION

Coffee is vegetatively propagated using either stem cuttings or grafting. Vegetative propagation of coffee by stem cuttings guarantees uniformity as it maintains the genetic make-up of the planting materials while propagation by seeds leads to genetic variability due to segregation of genes during fertilization (Kumar et al., 2006). An ideal propagation medium for successful rooting must be friable, sterile, have pH of 5.5 to 6.5 and well drained to ensure availability of oxygen and nutrients for seed germination, root initiation and seedling growth (Holloway, 2008; Gopale and Zunjarrao, 2011; Yeboah et al., 2011). Mixtures of sand and perlite at 1:1 (v/v), peat

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Table 1. Characteristics of five improved hybrid Arabica coffee varieties.

Variety name	Yield (kg/ha) clean coffee	Bean size (AA+A, %)	Stem size (cm)	Leaf size (mm^2)
N39-2	2,708	77	3.76	5,650
N39-3	2,763	74	3.61	6,100
N39-7	2,700	72	3.49	6,375
KP423-1	2,225	80	3.53	5,219
KP423-2	1,851	68	3.57	7,434

Source: Teri et al. (2011).

moss and coarse perlite 2:1 (v/v), and vermiculite and composts at 1:1 (v/v) have been recommended to promote rooting of cuttings (Chong et al., 2008; Pijut et al., 2011). It has been reported that increased rooting ability is associated with the type of rooting media, plant juvenility or age and growing conditions (Paparozzi, 2008). For instance, Yeboah (2009) reported a significant number of roots on stem cuttings of shea nut tree (*Vitellarria paradoxa*) using rice husk medium against sand and sand plus top soil at 1:1 (v/v). Similarly, Parthiban et al. (1999) reported a significant rooting percentage when stem cuttings of neem (*Azadirachta indica*) and kapok tree (*Ceiba pentandra*) were propagated in media containing soil, sand and farm yard manure at 1:1:1 (v/v). Gopale and Zunjarrao (2011) also documented a significant rooting of 78.2% when stem cuttings of *Jatropha curcas* were propagated in sand, soil and vermicompost at 1:1:1 (v/v) against 64% rooting in fine sand alone.

Tanzania coffee research institute (TaCRI) has been multiplying its new improved hybrid coffee by stem cuttings and cleft grafting using top forest soil, decomposed husk or decomposed saw dust either singly or mixed with fine sand at 2:1 (v/v) (TaCRI, 2011). However, the average rooting of stem cuttings from these improved coffee varieties has remained as low as 50% (TaCRI, 2011).

Several factors affect rooting such as rooting media, plant age and growing environment (Paparozzi, 2008). Rooting media is one of the major factors which determine rooting of coffee stem cuttings (Gopale and Zunjarrao, 2011; Yeboah et al., 2011) and this therefore underscores the need to evaluate alternative growth media for improving rooting ability of coffee stem cuttings. The objective of this study was to determine best growth media for improving rooting of stem cuttings from different new hybrid coffee varieties.

MATERIALS AND METHODS

Study area and plant

This experiment was conducted under a shade house on-station at TaCRI, Lyamungu, Moshi, Tanzania from October 2013 to February 2014. Top forest soil was collected at a depth of 1 to 10 cm from "Sawe" forest reserve in Moshi, Tanzania (Amri et al., 2009; Adugna et al., 2015). Peat moss was purchased from Balton Tanzania Limited in Arusha and fine sand soil was collected from Weruweru River. Red soil was collected at a depth of about 5 to 50 cm from Lushoto in Tanga region, Tanzania and sawdust was collected from carpentry workshops in Moshi town.

Uniform orthotropic stem cuttings of five improved hybrid coffee varieties of Bourbon type and pleasant aroma beverage quality were used and are shown in Table 1. Stem cuttings with 4 to 8 internodes were harvested in the early morning from 10 year old vigorous mother stocks at TaCRI nursery. The stem cuttings were prepared under a shade into three nodes with six leaves as described by Twardowski et al. (2012). Leaves were cut half to reduce water loss by transpiration (Rezende et al., 2010; TaCRI, 2011).

Growth media

Top forest soil, red soil and fine sand were sorted to remove rotten plant roots and leaves, and sieved using 2 mm sieve whereas rice husk and saw dust were left to decompose for two months. Forest soil was then mixed with fine sand at a ratio of 2:1 by volume (TaCRI, 2011). All types of the media were sterilized by heating at 80°C for 1 h, cooled for 24 h to 15°C and then moistened to 20 to 35% moisture content (Pijut et al., 2011; Yeboah et al., 2011). The physical and chemical characteristics of the rooting media were determined at the beginning of the experiment and are shown in Table 2. Remarks on the level of nutrients were based on FAO (1984) and Landon (1991). Nitrogen fertilizer (N.P.K-20: 10: 10) at a rate of 33.3 g/m^3 was incorporated into the rooting media prior to planting of the stem cuttings (Rezende et al., 2010; TaCRI, 2011).

Experimental design and treatments applications

A split plot experiment in a completely randomized design with four replications was used. The main factor consisted of five improved hybrid coffee varieties (N39-2, N39-3, N39-7, KP423-1 and KP423-2) and the sub-factor consisted of four types of rooting media (top forest soil + fine sand at 2:1 (v/v), red soil, rice husk, saw dust and peat moss).

Each rooting media was filled in a cement propagation box with a dimension of 4 m long, 1 m wide and 0.9 m deep and adjacent boxes were spaced at 0.2 m apart (TaCRI, 2011). The box had three layers of media namely gravels at the base (0.15 m thick) followed by each of the rooting media (0.15 m thick) and a top empty space (0.6 m). The basal ends (2 to 3 cm) of stem cuttings were sterilized by dipping into 5 g/L solution of copper oxychloride (50 WP) to control fungal diseases, and air-dried for 5 min and immediately planted into the rooting media (Rezende et al., 2010). A dibble was used to create a spacing of 5 × 5 cm and holes of 2.5 cm depth into which stem cuttings were planted (Akwaturila et al.,

Table 2. Physical and chemical characteristics of the growth media used for the study.

Media property	Peat moss	Saw dust	Rice husk	Red soil	Forest soil
Physical					
Moisture (%)	39.13***	39.13***	33.42**	27.8**	34.7**
Bulk density (g cm^{-3})	0.23*	0.23*	0.28**	0.81***	0.48**
Chemical					
pH	7.00***	6.30**	5.80**	4.00*	4.9*
Salt concentration (dS m^{-1})	0.10*	0.12*	0.14*	0.27*	0.46*
CEC (cmol (+) kg^{-1})	96.0***	51.0***	72.0***	4.00*	14.0**
Exchangeable Ca (cmol (+) kg^{-1})	54.67***	1.66*	1.48*	0.48*	6.23*
Exchangeable Mg (cmol (+) kg^{-1})	0.95*	0.58*	0.58*	0.39*	0.77*
Exchangeable K (cmol (+) kg^{-1})	0.96*	0.25*	0.91*	0.13*	0.82*
Available P (mg kg^{-1})	11.11*	18.69*	41.27**	0.66*	12.95*
Total N (%)	0.24**	0.17**	0.12**	0.06*	0.17**
Organic Carbon (%)	4.92***	11.14***	11.91***	0.73*	4.72***
Exchangeable Al (cmol (+) kg^{-1})	0.10*	0.10*	0.50*	2.66***	0.3*
Total Cu (mg kg^{-1})	0.44*	24.65***	8.53**	2.93**	4.25**
Total Fe (mg kg^{-1})	4.59*	216.31***	275.76***	402.61***	393.3***
Exchangeable Mn (mg kg^{-1})	41.98**	142.33***	132.40**	135.82**	102.50**
Exchangeable Zn (mg kg^{-1})	0.69*	13.18***	8.29**	12.02***	5.42**

Source: FAO (1984) and Landon (1991). *Low, **Medium and ***High.

2011; TaCRI, 2011). The total number of experimental units was 100 each with 30 stem cuttings. The media moisture content was monitored using a digital moisture meter (Ridde AG) and was adjusted to 20 to 35% by spraying with water using a knapsack sprayer (Gopale and Zunjarrao, 2011; TaCRI, 2011).

The planted stem cuttings were sprayed with 5 g/L solution of copper oxychloride (50 WP) using knapsack sprayer to control fungal diseases. The propagation boxes were covered with a transparent polythene sheet of 5 mm thickness under the black shade net with a shading capacity of 30%. These sheets were supported by semi-circular iron rods to preserve humid condition. Irrigation in fine droplets using a knapsack sprayer was applied when needed to maintain the water holding capacity at 20 to 35% of the rooting media. A relative humidity of 60 to 85% inside the propagation box was monitored by using hygrometer and maintained by misting using a knapsack sprayer (Pandey et al., 2011). Fungal diseases on the stem cuttings were controlled by applying 5 g/L solution of copper oxychloride (50 WP) whenever signs of fungal infections were observed (TaCRI, 2011).

Data collection and analysis

Data were collected four months from the date of planting by gently uprooting the stem cuttings as recommended by Yeboah et al. (2009). A stem cutting was considered to be rooted if it had at least one visible lateral root of ≥2 cm long (Ou-Yang et al., 2015). The following data were collected as described by Pandey et al. (2011):

(1) Number of rooted cuttings: Rooted stem cuttings was counted and converted into percentage.

(2) Number of lateral and fibrous roots: Laterals and fibrous roots were counted for each stem cutting.

(3) Root length: Longest lateral roots (cm) were measured with a graduated ruler from the collar to its apex.

Data collected were subjected to analysis of variance using CoStat software version 6.311 at P ≤ 0.05. The differences between the treatment means were separated based on Tukey's test at P ≤ 0.05.

RESULTS

Effect of hybrid coffee varieties on rooting of stem cuttings

Coffee varieties had a highly significant (P = 0.00) effect on rooting percentage of stem cuttings and number of lateral roots per cutting and a significant (P = 0.02) effect on root length. However, coffee varieties did not have significant (P = 0.11) effect on the total number of roots per cutting (Table 3).

Effect of media on rooting of stem cuttings of hybrid coffee varieties

Rooting media had a highly significant (P = 0.00) effect on rooting percentage, number of roots per cutting and root length, and a significant (P = 0.02) effect on number of lateral roots per stem cutting (Table 4).

Interaction effect of varieties and rooting media on rooting of stem cuttings

Interactions between varieties and rooting media were significant (P = 0.04) on percentage rooted cuttings,

Table 3. Effect of hybrid coffee varieties on rooting of stem cuttings.

Variety	Rooting percentage	Total no. of roots per cutting	Lateral root length (cm)	No. of lateral roots per cutting
N39-2	64.2^{a}	35.3	11.0^{ab}	2.3^{a}
N39-3	63.9^{a}	34.1	11.3^{a}	2.1^{ab}
N39-7	52.6^{b}	34.6	10.0^{b}	2.0^{b}
KP423-2	58.5^{ab}	33.6	11.1^{ab}	2.3^{a}
KP423-1 (control)	54.3^{b}	29.5	10.2^{ab}	2.3^{a}
Mean	58.73	33.46	10.70	2.19
CV (%)	25.08	39.86	23.17	27.39
P-values	0.00	0.11	0.02	0.00

Means followed by the same letter in the same column are not significantly different at P ≤ 0.05 according to Tukey's Test.

Table 4. Effect of rooting media on rooting of stem cuttings of hybrid coffee varieties.

Rooting media	Rooting percentage	Total no. of roots per cutting	Lateral root length (cm)	No. of lateral roots per cutting
Top forest soil + Sand (2:1)	63.0^{b}	20.0^{c}	10.9^{b}	2.35^{a}
Red Soil	77.9^{a}	40.1^{b}	10.7^{b}	2.24^{ab}
Rice husk	64.7^{b}	33.8^{b}	$10.3b^{c}$	2.08^{b}
Saw dust	68.5^{b}	54.1^{a}	12.2^{a}	2.19^{ab}
Peat moss	19.6^{c}	19.2^{c}	9.5^{c}	2.12^{ab}
Mean	58.73	33.46	10.70	2.19
CV (%)	31.70	46.50	20.28	23.64
P-values	0.00	0.00	0.00	0.02

Means followed by the same letter in the same column are not significantly different at P ≤ 0.05 according to Tukey's Test.

significant (P = 0.01) on lateral root length and highly significant (P = 0.00) on number of roots per cutting and number of lateral roots per cutting (Table 5).

DISCUSSION

Effects of hybrid coffee varieties on rooting of stem cuttings

In this study, hybrid coffee varieties exhibited differences in rooting percentage with varieties N39-2 and N39-3 producing the highest rooting percentage. This difference in rooting percentage is associated with their variation in genetic makeup which influence the amount of root promoting substances and interactions between genetic and environmental factors as reported earlier (Amissah and Bassuk, 2007; Gopale and Zunjarrao, 2011; Pijut et al., 2011). Previous studies have also documented that increasing rooting percentage was related to large leaves and stem sizes (Islam et al., 2010; Gehlot et al., 2015; Ou-Yang et al., 2015). For instance, stem cuttings from neem (*A. indica* A. Juss) with 0.5 to 1.5 cm diameters significantly increased rooting compared to cuttings with diameter of less than 0.5 cm (Gehlot et al., 2015). Similarly, the size of stem cuttings of pomegranate (*Punica granatum* L) with three buds had longer roots than those with a single bud (Alikhani et al., 2010).

Effects of media on rooting of stem cuttings of hybrid coffee varieties

The significant differences in rooting percentage observed among hybrid coffee varieties in this study were due to variation in chemical and physical properties of the growth media. The effect of chemical and physical characteristics of growth media on rooting of various tree species has been widely reported (Khayyat et al., 2007; Beyl, 2008; El-Naggar and El-Nasharty, 2009; Akwatulira et al., 2011). In the present study, red soil media resulted in the highest rooting percentage of the stem cuttings of hybrid coffee varieties. This high root ability of the cuttings in red soil media is associated with its lower pH of 4.0 and highest amount of micronutrients, namely, iron, manganese and zinc, which are known to stimulate rooting (Schwambachi et al., 2005). Harbage and Stimart (1996) have observed that rooting was significantly

Table 5. The effect of interaction between varieties and rooting media on root growth characteristics of hybrid coffee varieties.

Varieties × Rooting media	Rooting percentage	Total no. of roots per cutting	Lateral root length (cm)	No. of lateral roots
KP423-2 × Top forest soil + sand (2:1)	65.41^{ab}	57.7^{a}	10.9^{a-d}	2.5^{ab}
KP423-2 × Red soil	77.8^{ab}	21.5^{e-g}	10.9^{a-d}	2.4^{ab}
KP423-2 × Rice husk	72.9^{ab}	36.3^{b-f}	10.9^{a-d}	2.3^{ab}
KP423-2 × Saw dust	75.6^{ab}	20.0^{fg}	12.55^{ab}	2.2^{ab}
KP423-2 × Peat moss	29.4^{c-e}	41.2^{a-e}	9.6^{c-e}	2.3^{ab}
N39-3 × Top forest soil + sand (2:1)	59.4^{abc}	20.0^{fg}	11.9^{a-d}	2.2^{ab}
N39-3 × Red soil	83.7^{a}	15.7^{g}	11.5^{a-d}	2.1^{ab}
N39-3 × Rice husk	78.0^{ab}	28.6^{d-g}	10.7^{a-d}	1.9^{b}
N39-3 × Saw dust	74.6^{ab}	57.4^{a}	13.0^{a}	2.1^{ab}
N39-3 × Peat moss	23.9^{de}	49.1^{a-c}	9.2^{de}	2.0^{ab}
N39-7 × Top forest soil + sand (2:1)	65.4^{ab}	20.0^{fg}	10.2^{a-d}	2.1^{ab}
N39-7 × Red soil	77.1^{ab}	21.6^{e-g}	10.4^{a-d}	2.0^{ab}
N39-7 × Rice husk	47.1^{b-d}	35.8^{b-g}	9.6^{c-e}	2.0^{ab}
N39-7 × Saw dust	58.3^{a-c}	56.9^{a}	12.3^{a-c}	2.0^{ab}
N39-7 × Peat moss	15.2^{de}	38.9^{a-f}	7.4^{e}	1.8^{b}
KP423-1 × Top forest soil + sand (2:1)	59.4^{a-c}	20.0^{fg}	10.2^{a-d}	2.6^{a}
KP423-1 × Red soil	73.7^{ab}	15.7^{g}	10.1^{b-e}	2.3^{ab}
KP423-1 × Rice husk	61.7^{ab}	32.3^{c-g}	9.85^{b-e}	2.2^{ab}
KP423-1 × Saw dust	59.6^{a-c}	44.3^{a-d}	11.2^{a-d}	2.3^{ab}
KP423-1 × Peat moss	17.3^{de}	35.3^{b-g}	9.6^{c-e}	2.2^{ab}
N39-2 × Top forest soil + sand (2:1)	65.4^{ab}	20.0^{fg}	11.1^{a-d}	2.4^{ab}
N39-2 × Red soil	77.1^{ab}	21.5^{e-g}	10.6^{a-d}	2.4^{ab}
N39-2 × Rice husk	63.7^{ab}	36.1^{b-f}	10.5^{a-d}	2.1^{ab}
N39-2 × Saw dust	74.4^{ab}	54.3^{ab}	11.8^{a-d}	2.3^{ab}
N39-2 × Peat moss	12.1^{e}	36.1^{b-f}	11.5^{a-d}	2.2^{ab}
Mean	58.73	33.46	10.70	2.19
CV (%)	31.70	46.50	20.28	23.64
P-values	0.041	0.000	0.000	0.019

Means followed by the same letters in the same columns are not significantly different at $P \leq 0.05$ according to Tukey's Test.

influenced by pH of 5.5 against pH of 7.0 in three cultivars of apple. Furthermore, manganese has been involved in root growth and elongation in micro-cuttings of *Eucalyptus globulus* (Schwambach et al., 2011).

The longest lateral roots in this study were recorded in sawdust media. These results are associated to the lowest bulk density (0.23 g/cm^3), good aeration and high amount of manganese (142.3 mg kg^{-1}) in sawdust. According to Fagge et al. (2011), length and weight of roots in most cases are related to the type of rooting media. A well aerated medium enhances greater root penetration and favours metabolic activities for root initiation, which leads to formation of longer roots and high root growth rate (Gopale and Zunjarrao, 2011). Similar findings have also been reported in juvenile stem cuttings of *Buchholzia coriacea* when propagated in saw dust and top soil against river sand (Akinyele, 2010). Adugna et al. (2015) also reported significant root length of four nodal stem cuttings of vanilla using fine sand media with low bulk density.

CONCLUSION AND RECOMMENDATIONS

The objective of this study was to determine appropriate growth media for improving rooting of stem cutting of improved hybrid coffee varieties. Findings show that red soil media can increase rooting percentage of hybrid coffee varieties by 23.3% compared to the top forest soil + sand media at 2:1 (control) and by 13.7, 20.4, and 297.4% compared to sawdust, rice husk and peat moss media, respectively. Moreover, red soil media increases the number of roots per stem cuttings by 100.5% compared to the control and by 18.6 and 108.9% in comparison to the rice husk and peat moss media, respectively. This is the first study in which red soil media is reported to improve rooting of hybrid coffee varieties in Tanzania. It is recommended that red soil should be used as best rooting media for mass multiplication of hybrid coffee varieties. Further studies are required to improve further the chemical and physical properties of red soil.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Yield and quality performance of some peach varieties grown under Sanliurfa ecological conditions

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Peach has a wide range of adaptation to tropical, subtropical and temperate climatic zones around the world, hence is spreading as a fruit species. This study was done in a semiarid climate in Sanliurfa. The phenological, pomological and yield characteristics of 11 peach cultivars (Maycrest, Springcrest, Earlyred, Cardinal, Redhaven, Glohaven, Dixired, Cresthaven, Maria Marta, Elegant Lady and Monroe), were determined. Early flowering in the peach cultivars started on 14th March and ended on 8th April. The first flowering and the last flowering took place between 9 and 17 days. The full bloom to harvest of the cultivars took place between 74 (Maycrest) and 151 (Monroe) days. Based on the long-term observations, the earliest fruit maturation in peach varieties (Maycrest) occurred on the 2nd of June and the last fruit maturation occurred in Monroe on the 24th of August. The weights of the fruit varieties are as follows: Cardinal, 78.19; Dixired, 218.73; for TSS: Earlyred, 14.06; Maria Marta, 17.28%; for titratable acid content: Dixired, 0.47; Redhaven, 1.07 %; and for flesh firmness: Springcrest, 1.82; Dixired, 4.72 kg cm^{-2}. Between 2007 and 2011 years, cumulative yield values were found in Elegant Lady (166.87) and Earlyred (278.33 kg/tree).

Key words: Peach, *Prunus persica*, fruit yield, fruit quality, phenology, pomology, yield efficiency.

INTRODUCTION

Peaches and nectarines, which are temperate climate fruits, can be grown in subtropical and even tropical climate regions. They have developed varieties with low chilling requirement. Peach and nectarine are cultivated commercially mostly between 25 and 45° latitudes in the Northern and Southern hemispheres (Özbek, 1978; Westwood, 1993).

The motherland of peach (*Prunus persica* L.) is East Asia and China; it is grown in more than 80 countries around the world. Being the most important producer of peach-nectarine in the world, China ranks first with 12 423 700 tons of production, Spain is the second with 1 573 640 tons of production and Italy is the third with 3 379 428 tons of production. With 608 513 tons of peach-nectarine production, Turkey ranks 6th following Greece and the United States (FAO, 2014).

Peach and nectarine production in Turkey is limited due to the low winter and high summer temperatures, chilling

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requirement of the variety and late spring frosts. Having an important role in Turkey's agriculture and economy, the peach is widely grown in Marmara, Aegean, Mediterranean and Western Black Sea regions. In Turkey, 585 210 tons of peach are produced in 39 015 hectares of land. Mersin (103 595 tons), Çanakkale (91 558 tons), Bursa (77 941 tons), İzmir (74 311 tons) and Denizli (33 752 tons) are the leading peach producing cities of Turkey. Sanliurfa province has 49.2 hectares of area and 565 tons of peach production (TSI, 2016).

Breeding programs on peaches and nectarines have made it possible to grow peach-nectarine in subtropical and even tropical climatic regions. A number of studies have been carried out in many countries (Tsipouridis et al., 2002; Dumitru et al., 2003; Papanikolaou et al., 2005; Carter et al., 2006; Rakonjac and Živanović, 2008; Cline and Norton, 2012) and in Turkey (Kaşka and Küden, 1988; Kaşka et al., 1992; Önal and Ercan, 1992; Küden et al.,1995; Küden et al., 1997; Tosun et al., 2001; Ercan and Özkarakaş, 2003; Evliyaoğlu and Ferhatoğlu, 2003; Güven et al., 2007; Polat et al., 2010; Gür et al., 2011; Polat and Çalışkan, 2011; Gerçekçioglu et al.,2014) on the identification of the characteristics of various peach and nectarine varieties and their adaptation to various ecological conditions.

The aim of this study was to examine the performance of 11 peach varieties whose ripening period is between June and September under the conditions of Sanliurfa. It is expected that the findings of the study will guide the producers in Sanliurfa and Southeastern Anatolia Region on how to grow peach and contribute to the improvement of peach cultivation in the region.

MATERIALS AND METHODS

This study was carried out between 2008 and 2011 at Harran University, Faculty of Agricultural, Stone Fruits and Pome Fruits Research and Application Orchard on 11 peach varieties. They were budded on GF 677 rootstock and planted at 5×5 m planting distance.

In the research, Maycrest, Springcrest, Earlyred, Cardinal, Redhaven, Glohaven, Dixired, Cresthaven, Maria Marta, Elegant Lady and Monroe varieties were examined. The coordinates of the peach garden in which the research was conducted are 37°19' N, 38°96' E and the elevation is 515 m above sea level. The trees were pruned as "central leader tree"; the orchard was irrigated by drip irrigation system between May and October each year. Technical and cultural processes such as fertilization, disease and pest control were carried out regularly based on standards.

The soil (0 to 40 cm) of the orchard in which the study was done was moderate and fertile. The composition of the soil was determined as 40% clay, 33.2% silt, 21.4% sand, 0.82% organic matter and pH of 7.85 to 8.20. The content of organic matter, N, and P is low whereas the content of K is high (Anonymous, 2011).

The study was done in a Complete Randomized Block Design with 11 varieties, at 3 replications (3 trees in each replication). The phenological properties of the varieties such as bud swell, bud break, first bloom, full bloom, post bloom and harvesting period were observed.

The yield values were determined cumulatively for each tree by weighing the fruits harvested from the peach trees since 2008. The trunk diameters of the trees were measured at 15 cm over the graft point, and the yield values by unit trunk cross-sectional area (kg/cm^2) were determined.

Fruit weight (g), fruit height (mm), fruit width (mm), stone weight (g), hardness of the fruit (kg/cm^2), the brix (%), pH and titratable acidity (%) were determined by measuring 25 randomly selected fruits from each variety.

Angular transformation was applied to determine the percent values before statistical analysis. The findings of the research were designed and analyzed in a Randomized Complete Block Design using Duncan test for multiple comparison.

RESULTS AND DISCUSSION

Average temperature, average relative humidity, and annual total precipitation were measured as 18.5°C, 51.3% and 423 mm, respectively between 2008 and 2011 during the study. Most of the rainfall precipitates between November and April in Sanliurfa province. There is scarcely any rainfall in the hottest months of the year (June-September). The highest temperature was measured as 43.3°C in July and the lowest temperature was -4.2°C in February during the study period (Figure 1).

The phenological observations were made for the varieties included in the study between 2008 and 2011. The data about the earliest and latest occurrences of the observed phenological characteristic are shown in Table 1. The earliest bud swell was observed in Elegant Lady and Maycrest varieties on the 28th of February and the latest was observed in Cresthaven, Dixired and Glohaven varieties on the 13rd of March. The earliest bud break was observed in Maycrest variety on 9th of March, whereas the latest bud break was observed in Maria Marta variety on the 24th of March. The earliest first bloom in the peach varieties was observed in Maria Marta, Maycrest and Springcrest varieties on the 14th of March, whereas the latest first bloom was observed in Dixired variety on the 28th of March. The full bloom in the peach varieties (Dixired) occurred between 18th of March (Springcrest) and 3rd of April. While Maycrest variety (2nd of June) was the first to ripe harvest, while Monroe variety (11th of September) was the last; all the others were harvested between the time of these two varieties (Table 1).

The average time between bud swell and first bloom of the varieties was 14 days, the average time between first bloom and post bloom was 12 days, and the average time between full bloom and harvest was 108 days based on the calculations of the varieties' phenological results shown in Table 1.

In a research made in 1990 by GAP Koruklu Agricultural Research Station in Sanliurfa, it has been reported that all the peach and nectarine varieties had full bloom period between 19 and 23 March; Early Red's own was on the 21st of June; Armking (20th of June) from the nectarine varieties were the earliest to before harvest (Küden et al., 1997). During the second phase of the

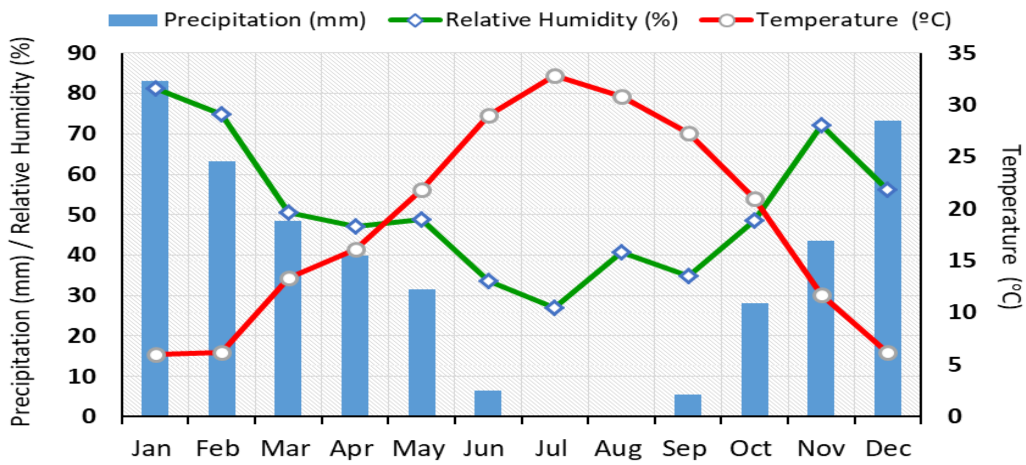

Figure 1. The average temperature, average relative humidity and average monthly rainfall data detected in the research garden (average of the years 2008-2011).

Table 1. Phenological observation results of peach cultivars between 2008 and 2011

Cultivar		Bud swelling	Bud burst	First bloom	Full bloom	End of flowering	Harvest date
Maycrest	Earliest	28.02	09.03	14.03	20.03	27.03	02.06
	Latest	10.03	17.03	22.03	27.03	02.04	11.06
Springcrest	Earliest	02.03	11.03	14.03	18.03	25.03	10.06
	Latest	11.03	19.03	25.03	29.03	04.04	22.06
Earlyred	Earliest	01.03	12.03	18.03	23.03	01.04	10.06
	Latest	11.03	18.03	22.03	27.03	03.04	24.07
Cardinal	Earliest	03.03	10.03	16.03	23.03	30.03	18.06
	Latest	10.03	20.03	25.03	30.03	05.04	03.07
Redhaven	Earliest	05.03	12.03	16.03	21.03	28.03	11.07
	Latest	11.03	21.03	27.03	31.03	05.04	04.08
Glohaven	Earliest	01.03	11.03	15.03	21.03	29.03	13.07
	Latest	13.03	22.03	27.03	31.03	05.04	26.06
Dixired	Earliest	05.03	16.03	20.03	25.03	03.04	16.07
	Latest	13.03	22.03	28.03	03.04	09.04	25.07
Cresthaven	Earliest	05.03	14.03	17.03	23.03	01.04	17.07
	Latest	13.03	23.03	27.03	31.03	05.04	18.08
Maria Marta	Earliest	02.03	11.03	14.03	19.03	26.03	22.07
	Latest	12.03	24.03	28.03	02.04	08.04	08.08
Elegant Lady	Earliest	28.02	10.03	16.03	21.03	28.03	07.08
	Latest	07.03	15.03	19.03	24.03	31.03	22.08
Monroe	Earliest	03.03	11.03	16.03	22.03	02.04	14.08
	Latest	10.03	17.03	22.03	27.03	02.04	11.09

research carried out in the same station between 1993 and 1997, it was determined that the average blooming dates of the peach and nectarine varieties in this period were between 7 and 27 March and the ripening period was between 10th of June and 22nd of August (Küden et al., 1997).

The adaptation of 20 peach-nectarine varieties was examined in Greece's Kos Island which has a chilling time of 150 h under 7.2°C and the city of Naoussa, Greece, which has a chilling time of 1000 h. Desert Gold (30th of January) was the earliest to bloom and Cardinal (6th of April) was the last to bloom in Kos Island. In the city of Naoussa, Desert Gold variety (7th of March) was the earliest to bloom while Morettini No. 1 variety (2nd of April) was the last to bloom (Papanikolaou et al., 2005).

Carter et al. (2006) examined the performances of 29 peach varieties in a study carried out in the Arkansas State of the US. The first bloom period, full bloom period, and optimum harvest period of the varieties examined in 2003 were determined as 09 to 15 March, 16 to 22 March, and 09 June to 02 August, respectively. In the study, the first bloom dates for Cresthaven, Glohaven and Rehhaven varieties were March 13, 14 and 13, respectively, the full bloom date for them was determined as March 22 and harvest dates were determined as 22 July, 14 July and 30 June, respectively.

'EarlyRed', 'Redhaven', 'Dixired', 'Washington', and 'J. H. Hale' peach varieties were examined in a research between 2002 and 2006 in Hatay province of Turkey. In this research, it was determined that the Earlyred variety bloomed (March 21) and ripened (June 6) earlier than the other peach varieties (Polat et al., 2010).

In a study conducted in the ecological conditions of Tokat province in Turkey between 2011 and 2012, the first bloom period of Elegant Lady, Monroe and Redhaven varieties of peach was between 28 March and 10 April, full bloom period was between 06 and 13 April, post bloom period was between 12 and 17 April and harvest period was 30 July to 9 September (Gerçekçioglu et al., 2014).

The chilling time (under +7.2°C) is 150 to 200 h for the examined peach varieties under Sanliurfa conditions and they were determined to bloom and ripe about 40 to 60 days later than those in Kos (Papanikolaou et al., 2005) and Rhodes (Tsipouridis et al., 2002); 30 days later than those in Cukurova region (Adana) (Son et al., 1995), 15 days later than those in Arkansas (USA) (Carter et al., 2006) and Hatay province (Polat et al., 2010), and 4 to 7 days later than those in Ceylanpınar District of Sanliurfa (Tosun et al., 2001) and Koruklu Research Station (Küden et al., 1997). However, they bloom and ripe about 4 to 7 days earlier than the varieties under Eğirdir's (Güven et al., 2007) and Tokat's (Gerçekçioglu et al., 2014) conditions, and 7 to 15 days earlier than the ones under Yalova's (Demiroren and Ufuk., 1996) conditions.

Yield per tree (kg/tree), cumulative yield (kg/tree), trunk cross-sectional area (cm^2) and its effect on cumulative yield (g cm^{-2}) values for peach varieties are as shown in Figures 2 and 3. Significant differences were determined between the varieties' yield per tree and cumulative yield values ($p < 0.01$ and $p < 0.001$).

Among the peach varieties studied, Earlyred variety had the highest yield per tree between 2008 and 2009; while for Maycrest, it was 2010; Earlyred, Redhaven, Maycrest, Dixired and Springcrest were determined to have the highest yield per tree in 2011.

Among the peach varieties, the highest cumulative yield between 2008 and 2011 (5 to 8 year-old trees) was 248.19 kg tree^{-1} from Earlyred variety, followed by Maycrest variety with 235.56 kg tree^{-1} (Figure 2). The Elegant Lady was determined to have the lowest cumulative yield (153.96 kg tree^{-1}).

The trunk cross-sectional areas range from 84.05 (Glohaven) to 146.52 cm^2 (Earlyred) and the cumulative yield-effect values range from 1.45 (Elegant Lady) to 3.03 kg cm^{-2} (Dixired) in 8-year-old peach trees under Sanliurfa's conditions (Figure 3).

Kaşka et al. (1992) examined 42 peach and 14 nectarine varieties' adaptation to the Mediterranean region in Alata Horticultural Research Institute between 1982 and 1990. The peach varieties' yields per tree range between 80 kg (Springtime) and 148 kg (Flordasun).

In a research conducted to determine the peach-nectarine varieties that could be grown under Harran Plain's conditions, it was reported that the Redhaven variety (39.19 kg tree^{-1}) ranked first, followed by Washington (38.69 kg tree^{-1}), Independence (37.81 kg tree^{-1}), J. H. Hale (36.72 kg tree^{-1}), Earlyred (36.01 kg tree^{-1}), Cresthaven (33.41 kg tree^{-1}), Nectared (33.36 kg tree^{-1}), Morettini (31.64 kg tree^{-1}), Red Globe (33.41 kg tree^{-1}) and Monroe (22.97 kg tree^{-1}) in terms of yield values (Evliyaoğlu and Ferhatoğlu, 2003).

Güven et al. (2007) examined 6-year old peach varieties (Cardinal, Cresthaven, Dixired, Earlyred, Elegant Lady, Glohaven, Maycrest, Monroe, Redhaven and Springcrest) and also examined in this study and obtained yield per tree ranging from 7.38 (Springcrest) to 39.81 kg (Elegant Lady) and cumulative yield values ranging from 29.13 (Dixired) to 96.56 kg tree^{-1} (Cresthaven). 7-year-old peach varieties ('Early Red', 'Redhaven', 'J. H. Hale', 'Washington' and 'Dixired') were studied under Dörtyol's (Hatay) conditions and yield per tree values were obtained ranging from 17.38 (J. H. Hale) to 41.51 kg tree^{-1} (Dixired) (Polat and Çalışkan, 2011). The researchers stated that the low yield per tree value is due to the fact that the rainfall in the region occurred in March and April, which is the varieties' blooming period, and also the low temperatures in the same period affected the fruit set negatively.

The cumulative yields between 2006 and 2010 of the 15 peach varieties planted in Southern Ontario (Canada) in 2004 ranged from 35.6 (V85384) to 332.6 kg ('Redhaven'), and the trunk cross-sectional area of the

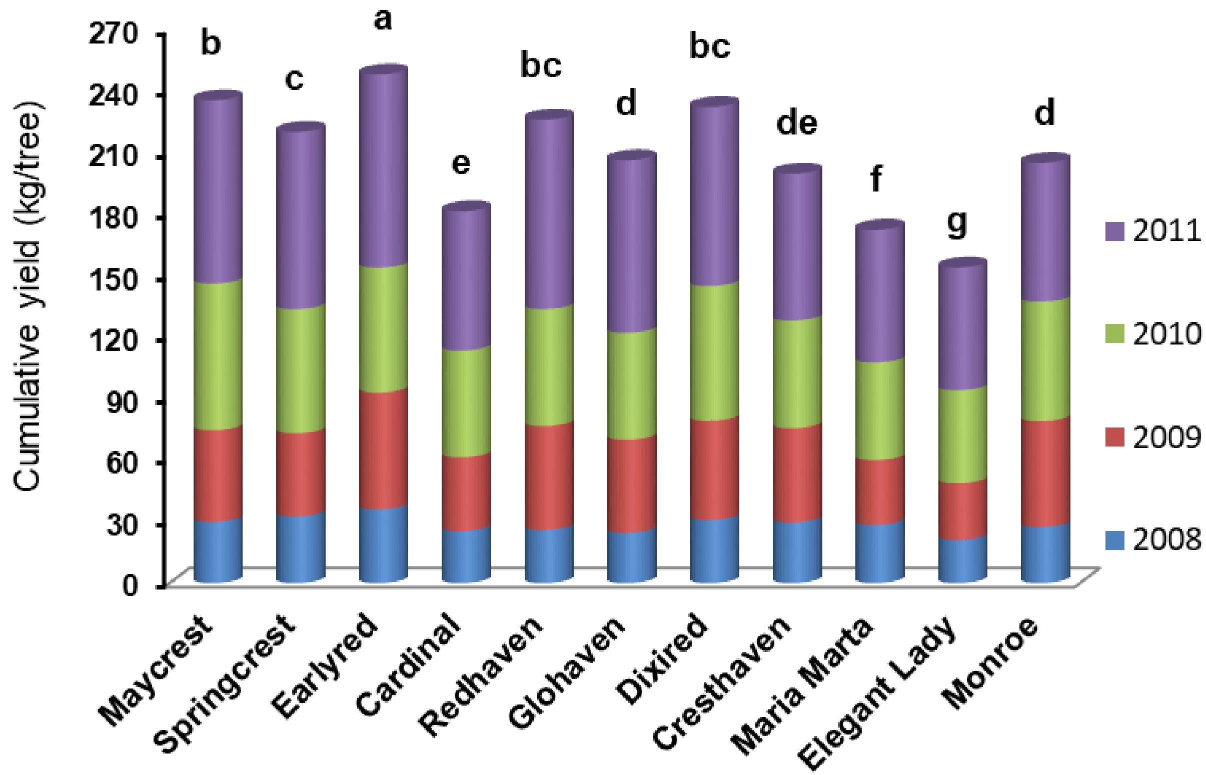

Figure 2. The cumulative yield per tree of peach varieties between the years of 2008 and 2011.

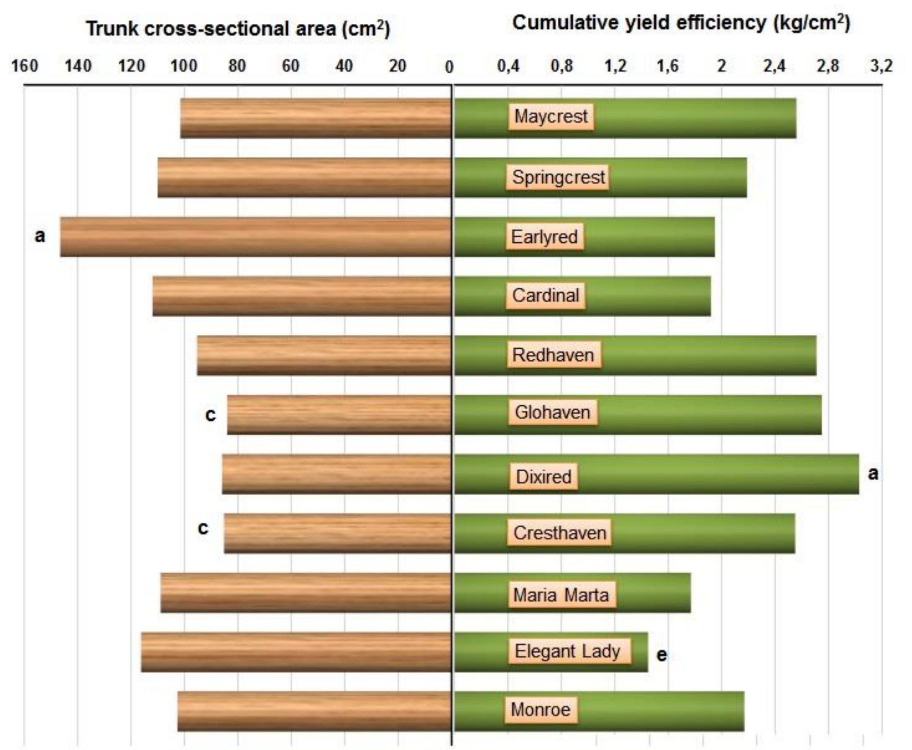

Figure 3. Trunk cross-sectional area and cumulative yield efficiency values of peach varieties in 2011.

Table 2. Some pomological properties of peach varieties.

Cultivar	Fruit weight (g)	Fruit width (mm)	Fruit length (mm)	Kernel weight (g)	Fruit flesh/Core ratio (%)	Fruit firmness (kg/cm^2)	TSS (%)	pH	Titratable acidity (%)
Maycrest	111.14^{bcd}	63.15^{bc}	58.94^{b}	9.29^{ab}	12.11^{cd}	2.76^{de}	16.64^{abc}	3.73^{bc}	0.58^{cde}
Springcrest	87.00^{def}	62.70^{bc}	59.00^{b}	4.36^{d}	20.53^{ab}	1.82^{f}	15.71^{a-d}	3.48^{de}	0.52^{de}
Earlyred	103.72^{b-e}	58.71^{c}	57.20^{bc}	7.37^{c}	14.16^{c}	2.21^{ef}	14.06^{d}	3.47^{de}	0.74^{bcd}
Cardinal	78.19^{fy}	50.73^{d}	48.48^{c}	5.06^{d}	15.89^{bc}	3.26^{bcd}	15.13^{cd}	3.78^{bc}	0.82^{abc}
Redhaven	125.81^{bc}	59.14^{bc}	60.75^{ab}	10.23^{a}	12.50^{cd}	2.19^{ef}	15.16^{cd}	3.82^{b}	1.07^{a}
Glohaven	115.15^{bc}	59.88^{bc}	55.27^{bc}	8.51^{bc}	13.71^{c}	3.59^{bc}	17.28^{a}	4.27^{a}	0.54^{de}
Dixired	218.73^{a}	74.37^{a}	76.70^{a}	8.24^{bc}	26.61^{a}	4.72^{a}	16.51^{abc}	3.36^{ef}	0.47^{e}
Cresthaven	129.58^{b}	61.69^{bc}	59.56^{b}	8.31^{bc}	15.67^{bc}	3.88^{ab}	17.13^{ab}	4.09^{a}	0.52^{de}
Maria Marta	102.29^{c-f}	64.08^{b}	58.88^{b}	8.27^{bc}	12.30^{cd}	3.81^{b}	14.58^{d}	3.60^{cd}	0.87^{ab}
ElegantLady	80.67^{ef}	60.47^{bc}	58.40^{b}	8.97^{ab}	9.00^{d}	3.87^{ab}	14.34^{d}	3.70^{bc}	0.82^{abc}
Monroe	102.31^{c-f}	59.15^{bc}	57.48^{bc}	7.60^{c}	13.55^{cd}	2.87^{cde}	15.38^{bcd}	3.24^{f}	0.48^{de}
P	**	**	***	**	***	***	***	***	***

[y]There is no statistical difference between the averages marked with the same letter (p<0.05). **, *** Significant at P< 0.01 or P< 0.001, respectively.

trees in 2010 range from 44.6 (Virgil) to 72.1 cm^2 (Harrow Dawn). Their effects on cumulative yield were identified ranging from 0.60 (Venture) to 2.73 kg cm^{-2} (Redhaven) (Cline and Norton, 2012).

The pomological characteristics of the fruits of the peach varieties examined in the research are shown in Table 2. The differences between the examined varieties regarding the pomological characteristics were statistically significant. In terms of fruit weight, fruit width and fruit height, Dixied variety (218.73 g, 74.37 mm and 76.70 mm, respectively) was ranked first among the varieties, whereas the Cardinal variety (78.19 g, 50.73 mm and 48.48 mm, respectively) was ranked last in terms of the same characteristics.

Şeker et al. (2007) examined the Early Red, J. H. Hale and Redhaven peach varieties grown in Çanakkale region and determined the fruit weight between 145.76 and 185.13 g, the fruit width between 67.13 and 70.23 mm, the fruit height between 58.43 and 69.64 mm, and the fruit hardness between 2.54 and 4.24 kg cm^{-2}, stone weight between 7.97 and 8.64 g, brix between 10.74 and 14.65% and total acidity between 0.28 and 0.49%. According to the pomological analysis results of 16 peach varieties examined in Eğirdir ecological conditions in 2006n to 2007, fruit weights ranged from 133.4 to 258 g, fruit width ranged from 59.7 to 88.0 mm, fruit height ranged from 59.7 to 82.6 mm, fruit hardness ranged from 0.74 to 2.6 kg cm^{-2}, pH ranged from 3.45 to 4.12, titratable acidity value ranged from 0.46 to 0.74% and brix ranged from 10.68 to 16.60% (Gür and Pırlak, 2011).

According to the average values of Elegant Lady, Monroe and Redhaven peach varieties that were grafted on GF 677 rootstock under Tokat's ecological conditions in 2011 to 2012, average fruit diameter was found to range between 54.89 (Elegant Lady) and 74.33 mm (Monroe) and average fruit height between 51.51 (Elegant Lady) and 71.79 mm (Monroe) (Gerçekçioglu et al., 2014). In the same research, the fruit hardness of Elegant Lady, Monroe and Redhaven peach varieties were determined as 7.05, 5.60 and 4.84 kg cm^{-2}, respectively, the brix values as 12.77, 12.30 and 13.08% respectively, pH as 3.92, 3.65 and 4.06 and titratable acidity as 1.20, 1.22 and 0.70, respectively (Gerçekçioğlu et al., 2014).

The average fruit weight obtained in this study is approximately 25% higher than the ones obtained in Kos Island and Rhodes Island, Greece (Tsipouridis et al., 2002; Papanikolaou et al., 2005), whereas they are 25 to 40% lower compared to the results obtained in the studies conducted in some of the major peach cultivating centers in Turkey such as Adana (Son et al., 1995), Isparta-Eğirdir (Güven et al., 2007), Yalova (Demiroren and Ufuk, 1996). The obtained results of the research carried out under ecological conditions of Sanliurfa in terms of fruit size, fruit height and width of some peach varieties were similar with the ones obtained in Koruklu/Sanliurfa (Küden et al., 1997), Ceylanpınar (Tosun et al., 2001), Hatay (Polat et al., 2010), and Tokat (Gerçekçioglu et al., 2014).

The stone weight of the peach varieties studied in this research ranged from 4.36 (Springcrest) to 10.23 g (Redhaven), the flesh/stone ratio ranged from 9.00 (Elegant Lady) to 26.61% (Dixired) and the hardness of the fruit flesh ranged from 1.72 to 4.72 kg cm^{-2} (Table 2).

The brix values of the peach varieties ranged from 14.06 (Earlyred) to 17.28% (Glohaven) (Table 2). On the other hand, the differences in pH values and titratable acidity of the fruits between the peach varieties were statistically significant.

The brix values of the varieties grown in Sanliurfa are higher than those grown in other regions of Turkey. It has also been found that the results obtained from this research are consistent with the results of the other pomological analyses tested under Eğirdir and Tokat conditions (Güven et al., 2007; Gür and Pırlak, 2011; Gerçekçioglu et al., 2014).

Conclusion

It is seen that the commercial peach orchard under ecological conditions of Sanliurfa can hardly be expected to have fruit quality to compete with important peach growing regions in Turkey. The high average temperature of over 35°C and the daily evaporation of over 20 mm/m^2 during summer in the region slow down the growth of peach fruits and cause quality loss such as fibrousness and shrivel due to evapotranspiration on the fruit walls. In this study, particularly the early peach varieties provided better results in terms of both yield and quality under Sanliurfa's (Southeastern Anatolian Region) conditions. Also, the brix value of the peach fruits grown under Sanliurfa's conditions has been found to be 30 to 40% higher than that of the peach fruits grown in other areas. From this perspective, it observed that the future potential of Sanliurfa province will be high in terms of peach and nectarine production for the fruit juice industry.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Effects of water hyacinth (*Eichhornia crassipes*) on the physicochemical properties of fishpond water and growth of African catfish

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Water hyacinth (*Eichhornia crassipes*) is an aquatic plant that has the capacity to absorb nutrients, making it a potential alternative for the management of fishpond water. The effect of this plant on the physicochemical properties of fish pond water and on the growth of African catfish was investigated in this study. Four plastic ponds 2.0×2.0×1.2 m deep were used for the study. Fifteen percent of the surface area of two of the ponds was covered with water hyacinth while the other two ponds, which served as the control, were left uncovered. African catfish juveniles, with an average weight of 0.3 kg, sourced from a commercial fish farm, were used to stock each of the ponds at a density of 30 m^{-2}. The fish were fed with commercial feed pellets at an average rate of 0.33 g/fish/day. Water samples were drawn from the ponds weekly and analyzed for relevant physicochemical parameters. Based on the observed oxygen content of the ponds, the water in the control ponds were changed every week while those of the ponds with water hyacinth were changed bi-weekly. Fish samples were randomly selected weekly from each pond and weighed to determine the fish growth. The study lasted for four weeks. Results showed that the mean concentrations of total dissolved solids (TDS), total hardness, Mg hardness, chloride, nitrate, nitrite, sulphate, conductivity, turbidity and dissolved oxygen (DO) were higher, but not significantly ($P \leq 0.05$), under water hyacinth cover. Other parameters such as ammonia and biochemical oxygen demand (BOD) were higher in the control pond. All parameters were fairly within the acceptable limits. There was also no significant difference ($P \leq 0.05$) between the final average weight of the fish in the ponds with water hyacinth (0.85 kg) and the control ponds (0.69 kg). Apart from reduction in water use, it would appear that the use of water hyacinth does not confer any significant advantage in fish ponds.

Key words: Fish pond, water hyacinth, *Eichhornia crassipes,* African catfish, physicochemical properties.

INTRODUCTION

Water is essential for the life of fish. It is the medium that must supply or support all their needs, including breathing, eating, reproduction, and growing (Infonet Biodivision, 2016). In commercial fish production, water is

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a major resource and constitutes a significant percentage of the production cost in fish ponds (Isyagi et al., 2009). The high feeding levels necessary to sustain semi-intensive and intensive fish culture systems contribute large amounts of nutrients in the pond water. This, if not controlled, leads to excessive algal growth and depletion of the oxygen content of the water which in turn affects the growth of the fish. Unless there is a way of rapidly removing the nutrient from the water, the pond water must be changed frequently for effective and efficient fish production. Frequent change of fish pond water naturally leads to increase in the production cost, especially where water is supplied by pumping (Isyagi et al., 2009). Water hyacinth is known to absorb nutrients from water bodies (Aoi and Hayashi, 1996; Snow and Ghaly, 2008; Adeniran, 2011; Ochekwu and Madagwa, 2013; Ugya and Imam, 2015) and so appears to be a good solution to the management of fish pond water.

Water hyacinth, *Eichhornia crassipes* (Mart.) is a floating vascular plant which is believed to have originated from South America. It is one of the world's most prevalent invasive aquatic plants (Villamagna, 2009; Gupta et al., 2012). Villamagna (2009) noted that water hyacinth is prevalent in tropical and subtropical water bodies where nutrient levels are often high due to agricultural runoff, deforestation, and insufficient wastewater treatment. Water hyacinth is comprised of approximately 90% water, making it very heavy to transport (Gopal, 1987; Gupta et al., 2012). It commonly forms dense, interlocking mats due to its rapid reproductive rate and complex root structure, reproducing both sexually and asexually (Mitchell, 1985; Gupta et al., 2012). Its capacity to absorb nutrients makes it a potential biological alternative to secondary and tertiary treatment for sewage and other contaminated water (Cossu et al., 2001; Adeniran, 2011; Ochekwu and Madagwa, 2013; Ugya and Imam, 2015). Furthermore, it is known to increase invertebrate abundance and diversity by providing habitat within its complex root system (Brendonck et al., 2003; Toft et al., 2003). The dense and intricately connected root system also provides refuge and nursery habitat for small and juvenile fish as well as zooplankton (Brendonck et al., 2003).

Information on the effect of water hyacinth on ponds, particularly on ponds stocked with African catfish, is scarce. There are very few studies that report the ecological effect of water hyacinth on aquatic bodies which make it difficult to understand fully how it may alter an ecosystem (Villamagna, 2009). Hence, it is necessary to investigate the effects of water hyacinth on a pond stocked with African catfish to determine the direct and indirect effects of this aquatic plant on fish ponds. Indeed, the lead author of this paper once visited a commercial fish farm in Abakaliki, Eastern Nigeria, in which one of the ponds had water hyacinth planted on the surface. The farmer believed that it results in higher fish production. However, there was no empirical data to support his belief. This study was therefore carried out to investigate the effect of water hyacinth on the water quality of fish ponds, stocked with African catfish as well as the fish growth. African catfish *(Clarias gariepinus)* was chosen for this study because it is the most predominantly reared fish in Nigeria.

MATERIALS AND METHODS

The experimental ponds

The study is a two factor (ponds with and without water hyacinth) experiment with two replications. Four experimental artificial ponds consisting of plastic tanks with dimensions of 2.0 × 2.0 × 1.2 m deep were used for this study. The ponds were located at Mosco Fish Farm in Enugu South Local Government Area, Enugu State, Nigeria. The ponds were placed side by side so as to keep them exposed to the same environmental conditions. The ponds were filled with water sourced from a near-by stream. They were stocked with post juvenile African catfish with an initial average weight of 0.3 kg, which was obtained from Mosco Fish Farm. The choice of the fish species is based on the fact that African catfish is the predominantly reared fish in Nigeria.

Experimental procedure

The experimental ponds were each filled with about 4 m^3 of water after which each of the ponds were stocked with 120 African catfish of post juvenile size giving a stocking density of 30 fish/m^2. Five fish from each of the ponds were randomly selected and weighed prior to stocking and after every 7 days subsequently. A conscious effort was made to ensure that the post juvenile fish that were stocked in the ponds were almost of the same average weight of 0.3 kg. Water hyacinth was planted to cover about 15% of the surface area of two of the ponds (Pond B1 and B2), while the control ponds (Pond A1 and A2) were left free of water hyacinth. The water hyacinth was placed manually in the pond as required to maintain the percentage cover. The fishes were fed with a commercially available floating feed pellet (SARB) daily. The average feeding rate was 0.33 g per fish per day. At the end of every week, five fishes were selected at random and weighed to determine the fish development. The water in the control ponds was drained and replaced with fresh stream water weekly while that in Ponds B1 and B2 were changed every two weeks as the dissolved oxygen content was found to be too low after the first two weeks. The experiment lasted for four weeks.

Before the stocking of the fishes in the ponds, a sample of the water was taken to determine the water quality and the subsequent effect of the water hyacinth on the quality of the fish pond water. Samples of the fish pond water were collected from the ponds around 11.00 am every 7 days using sterilized polyethylene bottles. The samples were stored at 4°C pending when analysis was done. These samples were analyzed for some selected aquatic water parameters.

Physicochemical analyses

The following physicochemical properties were investigated: temperature, conductivity, total dissolved solids, turbidity, pH, dissolved oxygen (DO), ammonia, nitrate, nitrite biochemical oxygen demand (BOD), chemical oxygen demand (COD), total hardness, calcium hardness, magnesium hardness, total alkalinity, chloride, phosphate, sulphate, calcium, magnesium, sodium, and potassium. The selection of these parameters was based on the

Table 1. Method employed in the physicochemical analyses.

S/N	Parameter	Method	S/N	Parameter	Method
1	pH at 250°C	APHA 4500H'B	11	Total Alkalinity (mg/L)	APHA 2320 B
2	Conductivity (µS/cm)	APHA 2510B	12	Chloride (mg/L)	APHA 4500Cl^-B
3	TDS (mg/L)	APHA 2501B	13	Nitrate (mg/L)	APHA 4500-$N0_3$E
4	Turbidity (NTU)	APHA 2130B	14	Nitrate (mg/L)	APHA 4500-$N0_2$B
5	Sodium (mg/L)	APHA 3500-Na B	15	Ammonia (mg/L)	APHA 4500 NH_3
6	Calcium (mg/L)	APHA 3500-Ca B	16	Sulphate (mg/L)	APHA 4500 SO_4^2E
7	Magnesium (mg/L)	APHA 2300-Mg B	17	Phospate (mg/L)	APHA 4500-P D
8	Total Hardness (mg/L)	APHA 2340C	18	Dissolved Oxygen (mg/L)	APHA 4500-OC
9	Ca Hardness (mg/L)	APHA 2500-Ca B	19	BOD (mg/L)	APHA 5210D
10	Mg Hardness (mg/L)	APHA 2500-Mg B	20	COD (mg/L)	APHA 5220D

suggestion by Chapman (1996) who stated that these parameters have medium to high impact on aquatic life and fisheries. The analyses were carried out following the procedure outlined in Standard Method for the Examination of Water and Wastewater (APHA and AWWA, 2012). The specific methods are listed in Table 1.

RESULTS AND DISCUSSION

Water quality parameters

The results of the physicochemical analyses of the water samples are shown in Table 2. A comparison of the result with the standard for fish pond water is also presented in the table. The parameters analyzed for and their units were: Temperature (°C), pH, Conductivity (µS/cm), Total Dissolved Solids (mg/L), Turbidity (NTU), Sodium (mg/L), Calcium (mg/L), Magnesium (mg/L), Total Hardness (mg/L), Ca Hardness (mg/L), Mg Hardness (mg/L), Total Alkalinity (mg/L), and Chloride (mg/L). Others are Nitrate (mg/L), Nitrite (mg/L), Ammonia (mg/L), Sulphate (mg/L), Phosphate (mg/L), Dissolved Oxygen (mg/L), BOD (mg/L), and COD (mg/L).

Temperature

Temperature is the single most important physical factor controlling the life of cold blooded animals. It is critical to growth, reproduction and sometimes survival (Masser, 1997). Figure 1 shows the variations in the temperature of the ponds. The temperature in both the control ponds (Ponds A) and the ponds with water hyacinth (Ponds B) exhibited the same pattern with an average value of 30.88±2.9°C in the control ponds and 30.98±2.72°C in the ponds with water hyacinth during the experimental period. The temperatures were highest during the second week and least during the third. These may have been due to changes in the environmental temperature.

Every species of fish has an optimum temperature for growth as well as upper and lower lethal temperatures. Infonet Biodivision (2016) recommended an optimum temperature of 21 to 27°C for African catfish although this catfish can thrive in warm ponds of up to 33°C (RFP, 2010). Bhatnagar et al. (2004) and Mayer (2012) indicated that a temperature of 25 to 37°C is generally tolerable to fish. Temperature above the optimum range increases the rate of bio-chemical activity of the micro biota and respiratory rate, and so increase in oxygen demand (Bhatnagar and Devi, 2013).

It further causes decreased solubility of oxygen and also increased rate of breakdown of waste and hence increased level of ammonia in water. At the lower temperatures of 15 to 26°C, there is reduced feed intake and decreased growth rate. Fish will not spawn at temperature below 20°C and growth stops at below 15°C (Infonet Biodivision, 2016). The temperature of 28.0 to 34.9°C recorded for the pond with water hyacinth was therefore fairly satisfactory in terms of feed intake, metabolism and growth. With similar range of temperature recorded in both the control ponds and the ponds with water hyacinth, it would appear that water hyacinth had no effect on the temperature of the pond.

pH

The variation of pH in the ponds during the study period is as shown in Figure 2. As with temperature, the pH of the two pond types followed similar pattern. The pH of the control pond was an average of 7.00±0.47, while that of the ponds with water hyacinth was an average of 6.98±0.60. The highest pH values were recorded in the two ponds during the second week.

Water hyacinth has been found to stabilize pH levels and temperature in experimental lagoons, thereby preventing stratification within the water column (Giraldo and Garzon, 2002). Fishes have an average blood pH of 7.4; a little deviation from this value, generally from 7.0 to 8.5, is conducive to fish life and for biological productivity in general. A pH value of 6.5 to 9.0 is generally acceptable for aquaculture ponds (Wurts and Durborow,

Table 2. Mean values of the physiochemical parameters analyzed for in the water samples from the fish ponds. (Pond A = Control; Pond B = Ponds with water hyacinth).

Parameter	Original stream	Week 1		Week 2		Week 3		Week 4		Standard	
		A	B	A	B	A	B	A	B	Acceptable	Optimum
Temperature (°C)	30.8	30.6	28.0	30.6	34.9	34.8	28.4	30	30.1	15 - 35	20-30[abc]
PH at 25 0°C	6.8	6.8	6.7	6.7	7.7	7.8	7.0	6.8	6.4	7 - 9.5	6.5-9.0[cde]
Conductivity (µS/cm)	71.6	151.0	304.0	153.0	280.0	428.0	222.0	152	133	3 -5000	100-2000[fg]
TDS (mg/L)	43.0	90.6	182.0	91.8	168.0	257.0	133.0	91.2	79.8	-	500-1200[hi]
Turbidity (NTU)	22.2	36.9	106.0	48.8	64.0	70.0	70.0	44.2	86.0		30 - 80cm[j]
Sodium (mg/L)	2.24	2.9	5.4	3.55	2.7	0.9	4.2	3.6	3.4	NA	NA
Calcium (mg/L)	4.0	3.2	16.0	3.2	7.2	10.4	10.4	4.8	4.8	4 - 60	25-100[d]
Magnesium (mg/L)	6.0	11.0	1.9	10.0	4.32	6.72	2.9	3.36	8.16	NA	NA
Total Hardness (mg/L)	16.0	19.0	18.0	86.0	54.0	48.0	38.0	26.0	46.0	>20	25-100[k]
Ca Hardness (mg/L)	10.0	8.0	40.0	8.0	18.0	26.0	26.0	12	12.0	-	-
Mg Hardness (mg/L)	6.0	11.0	8.0	10.0	18.0	28.0	12.0	14	34.0	-	-
Total Alkalinity (mg/L)	14.0	48.0	156.0	40.0	150.0	210.0	112.0	64	50.0	20 - 400	75-200[dg]
Chloride (mg/L)	4.0	6.0	14.0	7.0	5.0	2.0	18.0	8	8.0	>60	60-100[k]
Nitrate (mg/L)	2.6	7.2	10.4	18.5	15.1	43.7	28.5	1.7	2.1	0-200	0.1-4.5[ek]
Nitrite (mg/L)	0.05	0.56	0.01	2.95	0.03	0.01	0.01	0.01	0.28	0-4	<0.02[cgk]
Ammonia (mg/L)	0.5	6.2	33.0	4.5	23.0	25.0	24.0	5.4	3.8	0.6-2.0	<0.025[klm]
Sulphate (mg/L)	9.0	12.0	22.0	18.0	20.0	25.0	20.0	15	12.0	-	-
Phosphate (mg/L)	2.02	1.95	4.36	1.86	2.3	2.63	3.34	2.04	1.88	3.5	0.05-0.07[cg]
Dissolved oxygen (mg/L)	7.2	5.0	1.0	8.1	1.5	1.0	1.0	1.8	5.3	1-10	5[ckln]
BOD (mg/L)	4	30	730	40	250	350	590	72	50	3-6	1-2[k]
COD (mg/L)	5.0	35.0	760.0	46.0	368.0	501.0	610.0	231	229.0	-	-

[a]Turker and Robinson (1990); [b]Infonet Biodivision (2010); [c]Bhatnagar et al. (2004); [d]Wurts and Durborow (1992); [e]Santosh and Singh (2007); [f]Behar and Montpelier (1997); [g]Stone and Thomorde (2004); [h]Sarkar (2002); [i]Keremah et al. (2014); [k]Bhatnagar and Devi (2013); [l]Robinette (1976); [m]Swan (1997); [n]Masser (1997); NA: Not available.

1992; Bhatnagar et al., 2004; Santhosh and Singh, 2007; Mayer, 2012, Infonet Biodovion, 2016; Swan, 2017). Fishes can become stressed in water when the pH ranges from 4.0 to 6.5 and from 9.0 to 11.0. Death is almost certain at a pH of less than 4.0 or greater than 11.0 (Ekubo and Abowei, 2011; Bhatnagar and Devi, 2013). The pH values recorded in the two ponds are within acceptable level implying that the use of water hyacinth does not adversely affect the pH of fish ponds.

Hardness

Hardness is a measure of the amount of multivalent cation such as Fe, Ca, Mg, Al, Mn, Zn, etc., present in the sample. Calcium and magnesium are by far the greatest source of hardness in pond water. The mean hardness of the water samples from the ponds are shown in Figure 3. The total hardness increased from the value of 16.00 mg/L at the start of the study to a maximum value of 86.0 mg/L (as $CaCO_3$) by the second week. It subsequently decreased down to a value of 26.0 mg/L by the fourth week. For the pond with water hyacinth, the total hardness increased from 16.0 mg/L at the start of the experiment to a maximum value of 54.0 mg/L by the second week. It dropped to a value 38.0 mg/L

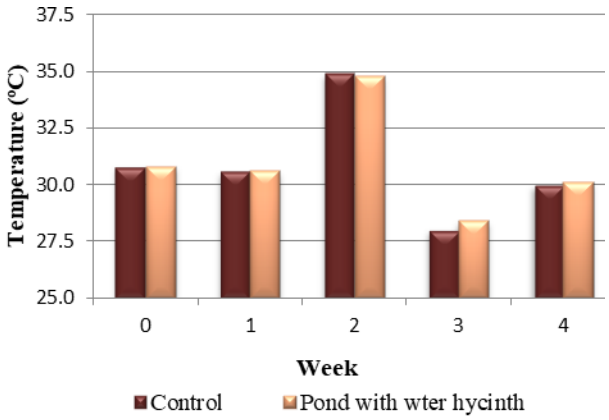

Figure 1. Variation of temperatures in the ponds during the study.

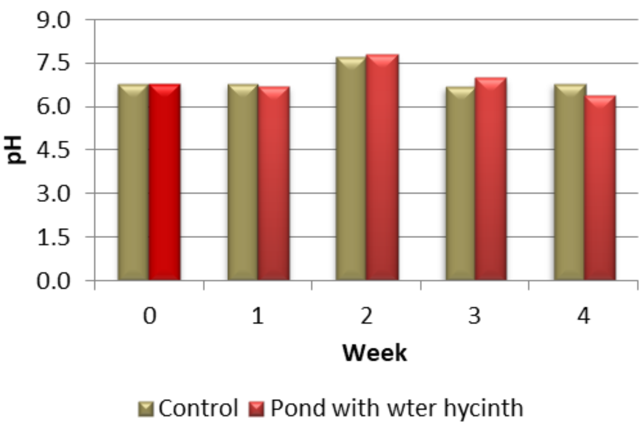

Figure 2. Variation of pH in the ponds during the study.

by the third week before rising to 46.0 mg/L at the end of the study. The total hardness in Ponds A and B was an average of 44.75±12.61 and 39±15.45 mg/L, respectively. The Ca hardness was an average of 19.50±14.27 mg/L in the control ponds and 18.00±9.38 mg/L in the ponds with water hyacinth while the Mg hardness values were 12.75±4.27 and 21.00±11.83 mg/L, respectively.

The increase in total hardness may be attributed to the presence of excess unconsumed feed in the water, while the relatively lower values recorded in the ponds with water hyacinth may be due to the absorption of some of the hardness-causing elements in the water by the water hyacinth.

The generally acceptable value of hardness for fish culture is at least 20 mg/L (Swann, 1997) with an optimum range of 30 to 180 mg/L as $CaCO_3$ (Stone and Thomforde, 2004; Santhosh and Singh, 2007; Swan, 2017). Hardness values less than 20 mg/L causes fish stress while values greater than 300 mg/L is lethal to fish life as it increases pH, resulting in non-availability of nutrients (Bhatnagar et al., 2004). The average hardness values obtained in the two pond types were fairly within the optimum range for fish ponds.The water hyacinth did not significantly affect the hardness of the fishpond water. Also, with the higher magnesium hardness level in the ponds with water hyacinth, it would appear that Mg is relatively less easily absorbed by water hyacinth.

Total alkalinity

Alkalinity is the water's ability to resist changes in pH and is a measure of the total concentration of bases in pond water including carbonates, bicarbonates, hydroxides, phosphates, borates, dissolved calcium, magnesium, and other compounds in the water (Bhatnagar and Devi, 2013). The average total alkalinity in the control ponds was 104.50±56.44 mg/L while that of the ponds with water hyacinth was 103±78.12 mg/L (Figure 4). An alkalinity value of 75 to 200 mg/L is considered ideal for fish ponds (Wurts and Durborow, 1992), although a range of 20 to 400 mg/L may be acceptable (Stone and Thomforde, 2004; Swann, 2017), For catfish production, the alkalinity must be at least 20 mg/L for good fish pond productivity (Swann, 1997; Steven, 2009; PHILMINAQ, 2017). The alkalinity levels recorded in the two pond types were fairly within the range showing that the water hyacinth had no effect on the alkalinity. In particular, the alkalinity was above the value of 20 mg/L as recommended for African catfish.

Dissolved oxygen (DO)

The principal source of oxygen in water is atmospheric air and photosynthetic planktons (Bhatnagar and Devi, 2013). DO affects the growth, survival, distribution, behavior and physiology of fish and other aquatic organisms (Mayer, 2012).

The DO level in the control ponds (Pond A) was an average of 2.33±1.81 mg/L while that of the ponds with water hyacinth was 3.85±3.48 mg/L (Figure 5). At the end of the first week, the DO content of Pond B had risen from an initial value of 7.2 mg/L at the start of the experiment to 8.1. By the second week it had gone down to 1.0 mg/L. Despite the necessary change of the water in the ponds at this point, the DO remained at the level of1.0 mg/L until the fourth week when it rose to 5.1 mg/L. For the control ponds, despite the weekly change of the water, the DO level also went down to 1.0 mg/L but by the third week. As noted by Villamagna (2009), dissolved oxygen levels can reach dangerously low levels for fish when large water hyacinth mats prevent light infiltration or when a relatively large area of plants decompose at the same time. Photosynthesis beneath water hyacinth mats is also limited as the plant itself does not release oxygen into the water as do phytoplankton and other submerged

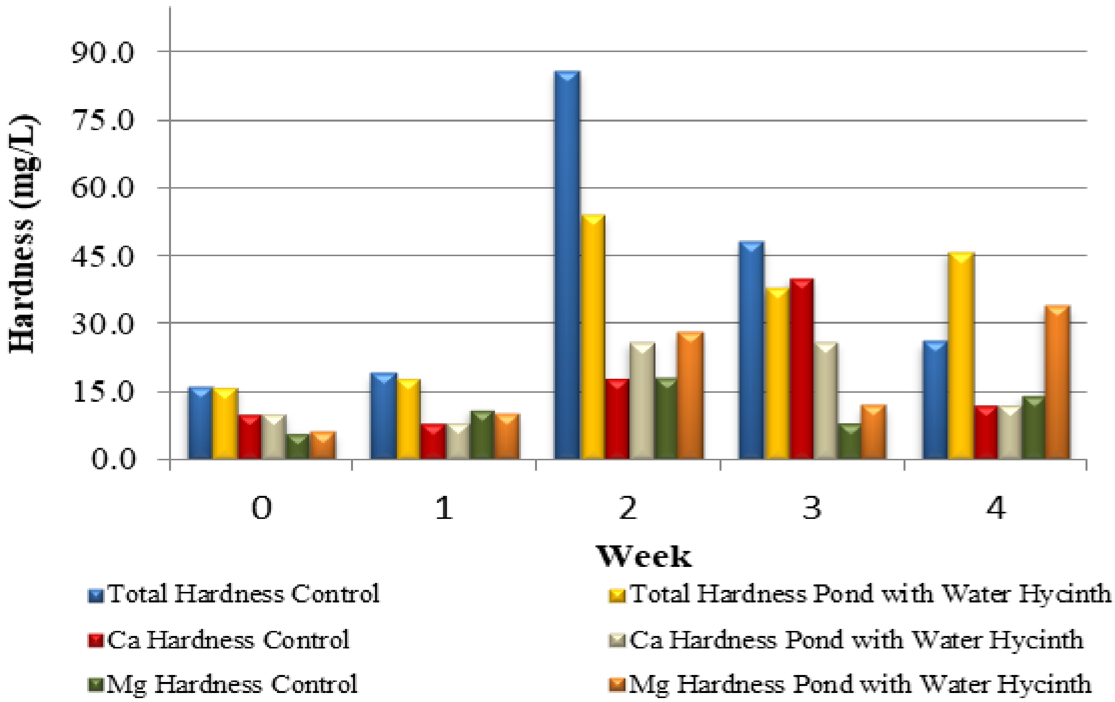

Figure 3. Total, Mg and Ca hardness of the water in the ponds during the study period.

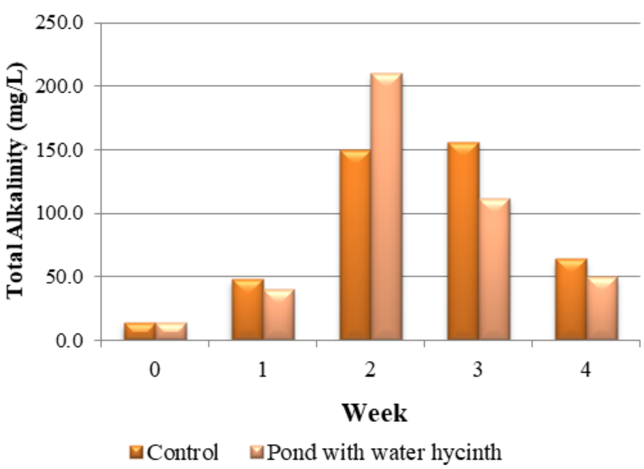

Figure 4. Variation of alkalinity in the ponds during the study.

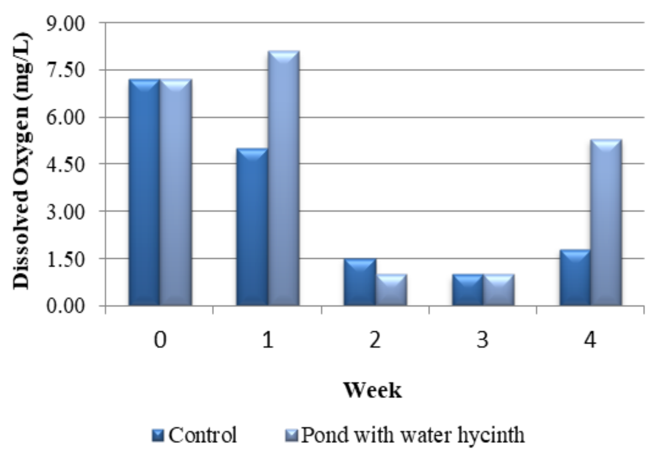

Figure 5. Variation of DO in the ponds during the study.

vegetation, resulting in decreased levels of dissolved oxygen concentration (Meerhoff et al., 2003; Troutman et al., 2007; Toft et al., 2003). However, as noted by McVea and Boyd (1975), a water hyacinth cover of up to 25%, does not cause DO to reach levels that threaten fish survival (that is < 2 mg/L). McVea and Boyd (1975) also reported an inverse relationship between dissolved oxygen and water hyacinth cover.

Oxygen depletion in water leads to poor feeding of fish, starvation, reduced growth and fish mortality, either directly or indirectly (Bhatnagar and Garg, 2000). DO level greater than 5.0 mg/L is essential to support good fish production (Bhatnagar et al., 2004). Catfish and other air breathing fish can, however, survive in oxygen concentration as low as 1.0 mg/L (Santhosh and Singh, 2007; Bhatnagar and Singh, 2010; RFP, 2010; Infonet Biodivision, 2016; Swan, 2017). According to Banerjea (1967), DO between 3.0 and 5.0 mg/L in ponds is unproductive. Tropical fishes have more tolerance to low DO than temperate fishes (Bhatnagar and Garg, 2000).

DO level of 1 to 3 mg/L has sub-lethal effect on growth

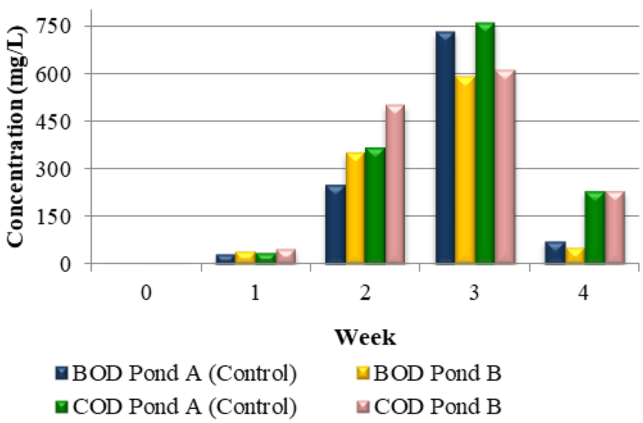

Figure 6. BOD_5 and COD concentration in the two ponds during the study. Pond A = Control; Pond B = Pond with water hyacinth.

and feed utilization. Although, African catfish and other healthy warm water fish can tolerate 1.0 mg/L DO for short periods of time, they will die if exposure is prolonged (RFP, 2010; Swann, 2017) or grow sluggishly if they survive. Generally, DO less than 1.0 mg/L or greater than 14.0 mg/L can have lethal effect of the fish (Bhatnagar and Devi, 2013). At high DO concentration gas bubble disease may occur (Bhatnagar et al., 2004). The observed DO values in the two pond types were fairly satisfactory except for the second and third week when it dropped to 1.0 mg/L. Although, as noted by Villamagna (2009), large water hyacinth mat could lead to a dangerously low oxygen level, it would appear that with 15% water hyacinth cover, such low O_2 level may not be attained for a prolonged period of time as long as the water in changed after a maximum period of two weeks. No mortality was recorded during the study.

BOD_5 and COD

BOD is an indirect measurement of the biodegradable organic matter content of water sample while the COD measures their total organic matter content. The 5-day BOD (BOD_5) and the COD of the water samples from the two ponds are shown in Figure 6. With a BOD and COD of 4.1 and 5, respectively, the stream water used in filing the ponds was not free of organic matter. The BOD of the control ponds increased steadily from 30 mg/L at the end of the first week to a maximum of 730 mg/L in the third week before declining to a value of 72 mg/L by the end of the experiment with an average value of 320.83±270.50 mg/L. The COD also increased similarly from 35 to 760 mg/L within the same period before decreasing to 231 mg/L. The average value of COD in the control pond was 348.50±306.49 mg/L. In the ponds with water hyacinth the BOD rose from 40 to 590 mg/L with an average value of 264.24±257.50 mg/L while the COD increased from 46 to 610 mg/L at the third week before declining with an average value of 346.50±256.52 mg/L. The increase in the organic matter content of the pond water may be due to accumulation of unconsumed feed and fish waste discharges in the water. The relatively lower values recorded in the ponds with water hyacinth may be due to the absorption of the organic matter by the water hyacinth.

Clerk (1986) reported that BOD range of 2 to 4 mg/L does not show pollution level of concern while levels beyond 5 mg/L are indicative of serious pollution. The recommended optimum BOD for aquaculture ponds is a maximum of 10 mg/L (Santhosh and Singh, 2007; Bhatnagar and Singh, 2010; Mayer, 2012). The greater the BOD, the more rapidly oxygen is depleted. Although the BOD and COD levels in the ponds with water hyacinth were slightly lower than those of the control, the BOD levels in the two pond types were very high and may have affected the performance of the fish. Perhaps, if the water in the ponds were changed more frequently, the organic matter level may not have been so high.

Cations (Sodium, Calcium, and Magnesium)

The concentrations of sodium, calcium, and magnesium in the two ponds are as shown in Figure 7. The average sodium concentration in the control pond was 3.65±1.23 mg/L while that of the ponds with water hyacinth was 3.01±1.45 mg/L. The lowest and highest value of sodium concentration was recorded during the second and third week, respectively in both pond types. Sodium (and potassium) is the most important salts in fish blood and are critical for normal heart, nerve, and muscle function (Wurts and Durborow, 1992).

The mean concentration of calcium in the control pond was 7.8±5.97, while that of the ponds with water hyacinth was 7.2±3.75. These values are lower than the value of 16.0 to 50.6 recorded by Ehiagbonare and Ogunrinde (2010) when they analyzed water samples from some four fish ponds in Okada, Edo State, Nigeria. Calcium plays an important role in the biological processes of fish. It is necessary for bone formation, blood clotting, and other metabolic reactions (Boyd, 2015). Calcium is also important for egg and larvae development (Stone et al., 2013). The presence of free (ionic) calcium at relatively high concentrations in fish culture water helps reduce the loss of other salts (e.g. sodium and potassium) from fish body fluids. The recommended optimum range of calcium in fish culture water is 25 to 100 mg/L (Wurts and Durborow, 1992; Boyd, 2015). Acceptable range is from 4.0 to 160.0 mg/L (Swann, 2017). Calcium concentration of less than 10.0 mg/L or greater than 350.0 mg/L induces stress on the fish (Bhatnagar and Devi, 2013).

Channel catfish can tolerate low level of mineral calcium in their feed but may grow slowly under such

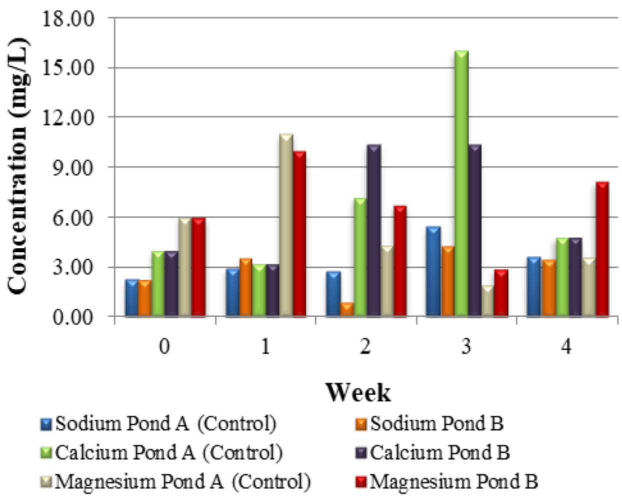

Figure 7. Mean concentrations of sodium, calcium and magnesium in the two ponds during the study. Pond A = Control; Pond B = Pond with water hyacinth.

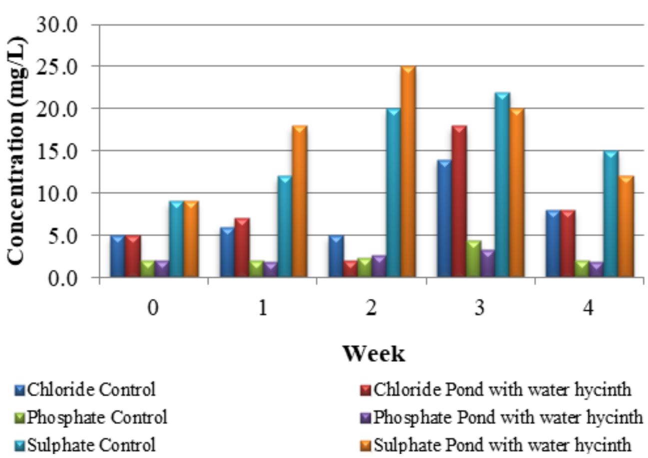

Figure 8. Anion concentrations in the fish ponds.

conditions. The calcium content of both ponds was within tolerable limits.

Magnesium content ranged from 1.9 to 11.0 mg/L in the control ponds with an average value of 4.92±4.29 mg/L. The highest and lowest values occurred during the third and first week, respectively. For the ponds with water hyacinth, the values ranged from 2.9 to 10.0 mg/L with a mean value of 6.95±3.01 mg/L. The highest and lowest values also occurred during the third and first week, respectively. The higher concentration of Mg in the ponds with water hyacinth may indicate, as earlier stated, that water hyacinth does not readily absorb Mg. Magnesium is not normally a limiting factor in freshwater aquaculture; it is essential for fish growth, but a specific recommended concentration is not available (Stone et al., 2013).

Anions (Chloride, Phosphate and Sulphate)

Chloride is essential in helping fish maintain their osmotic balance. Chloride content of water is dependent on its salinity level among other factors (Bhatnagar and Devi, 2013). The desirable level of chlorides concentration for commercial catfish production is above 60 mg/L. If the level of chloride relative to nitrite is maintained at the ratio of 10:1, nitrite poisoning, caused by excess nitrite in the pond water and which gives rise to “brown blood” disease in catfish, is eliminated (Stone and Thomforde, 2004). If the chloride level is higher than 100.0 mg/L, it results in the burning of the edges of the gills of the fish with long term after effects (Bhatnagar and Devi, 2013).

The mean chloride levels in the control ponds and the ponds with water hyacinth were 8.5±4.04 and 8.75±6.7 mg/L, respectively (Figure 8). The chloride concentrations in the two ponds were below the optimum level.

Phosphorous is a limiting nutrient needed for the growth of all aquatic and other plants. However, excess concentrations especially in rivers and lakes can result to algal blooms. Phosphates are not toxic to people or animals, unless they are present in very high levels. Digestive problems could occur from extremely high levels of phosphates. Phosphate concentration ranged from 1.9 to 4.36 mg/L in the control ponds with a mean value of 2.66±1.14 mg/L. In the ponds with water hyacinth, it ranged from 1.86 to 3.4 mg/L with an average of 2.43±0.71 mg/L (Figure 8). A phosphate level of 0.05 to 0.07 mg/L is desirable for optimum production (Bhatnagar et al., 2004; Stone and Thomforde, 2004; RFP, 2010); although Swann (2017) gave a tolerable limit of 0.01 to 3.0 mg/L. The phosphate concentration in the ponds was relatively high and could result in excess vegetative growth. This was however not noticed in the experimental ponds.

Sulphate (SO_4) is a naturally occurring compound in surface and ground waters. Concentrations can range naturally from 0 to 1,000 mg/L. Fishes have a wide range of tolerance for sulphate. The mean sulphate level in the control ponds was 17.25±4.57 mg/L, while that of the pond with water hyacinth was 18.75±5.38 mg/L (Figure 8). These are within the acceptable limits.

Nitrogen

Nitrogenous organic wastes come from uneaten feeds and excretion of fishes. Ammonia-Nitrogen (NH_3-N) is the primary nitrogenous waste produced and excreted by fish in a fish pond. Thus, the concentration of ammonia-N is positively correlated to the amount of food wastage and the stocking density (Bhatnagar and Devi, 2013). The average ammonia concentration was 16.9±13.46 mg/L in the control ponds and 14.33±11.76 mg/L in the ponds with water hyacinth (Figure 9).

The unionized form of ammonia (NH_3) is extremely toxic while the ionized form (NH_4^+) is generally harmless

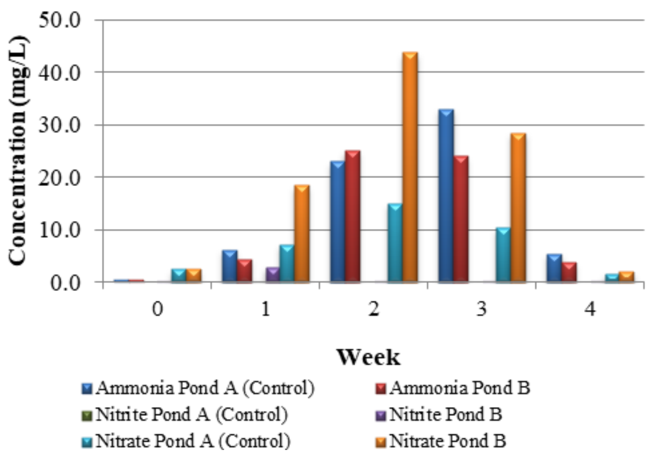

Figure 9. Mean nitrogen concentration in the control ponds (Pond A) and the ponds with water hyacinth (Pond B).

and can dissipate into the atmosphere easily (RFP, 2010; Bhatnagar and Devi, 2013). Ammonia concentration below 0.02 mg/L is considered safe (Swann, 1997, 2017); for short term exposure NH_3 level of 0.6 to 2.0 mg/L can be tolerated in fish pond (Robinette, 1976). High ammonia concentration (>0.1 g/mL) causes an increase in pH and ammonia concentration in the blood of the fish. This can damage gills and red blood cells, destroy mucous-producing membranes, affect osmo-regulation and reduce the oxygen carrying capacity of the blood while increasing the oxygen demand of the tissues (Lawson, 1995; Bhatnagar and Devi, 2013). It can also reduce growth and results in poor feed conversion.

Fish suffering from ammonia poisoning generally appear sluggish or often at the surface gasping for air (Bhatnagar and Devi, 2013). However, the level of ammonia toxicity depends on the fish species, water temperature and pH (Masser, 1997); its toxicity increases with an increase in temperature and/or pH, with pH being the most important factor (RFP, 2010). With NH_3 levels of up to 33.0 and 25.0 mg/L recorded, respectively in Ponds A and B, it is obvious that the fish suffered from ammonia toxicity. However, as stated earlier, no mortality was recorded during the study.

Nitrite (NO_2) is an intermediary product which results from the conversion of NH_3 or NH_4^+ into nitrate (NO_3). Like ammonia, nitrite is highly toxic to fish. It oxidizes haemoglobin to methemoglobin in the blood, turning the blood and gills brown and hindering respiration (Lawson, 1995; Bhatnagar and Devi, 2013). It also damages the nervous system, liver, spleen and kidneys of the fish. The level of toxicity depends on chemical factors such as the reduction of calcium, chloride, bromide, and bicarbonate ions and levels of pH, dissolved oxygen, and ammonia. The desirable level of nitrite in pond water should be 0 to 1.0 mg/L (Bhatnagar et al., 2004; Stone and Thomforde, 2004; Mayer, 2012). However, a concentration of less than 4.0 mg/L is acceptable (Stone and Thomforde, 2004; Swann, 2017). The nitrite concentration recorded ranged from 0.01 to 0.56 with an average of 0.15±0.27 mg/L in the control pond. In the pond with water hyacinth, it ranged from 0.01 to 2.95 with an average of 0.81±1.43 mg/L (Figure 9). These are fairly within acceptable level. As with other parameters, the water hyacinth did not seem to affect the nitrite level in the ponds.

Nitrate (NO_3) is formed through nitrification process, that is, oxidation of NO_2 into NO_3 by the action of aerobic bacteria. The mean nitrate concentration recorded 8.6±5.63 mg/L in the control ponds and 23.2±17.47 mg/L in the ponds with water hyacinth (Figure 9). Nitrate is generally stable over a wide range of environmental conditions and is highly soluble in water. Compared with other inorganic nitrogen compounds, it is relatively non-toxic (Stone and Thomforde, 2004). However, high levels can affect osmoregulation, oxygen transport, eutrophication and algal bloom (Lawson, 1995). The desirable concentration of nitrate in fish culture water is 0.1 to 4.0 mg/L (Santhosh and Singh, 2007); a concentration of 0 to 200.0 mg/L is however acceptable (Meck, 1996; OATA, 2008; Bhatnagar and Devi, 2013). The nitrate levels recorded in the two pond types are within acceptable level.

Conductivity and total dissolved solids (TDS)

Conductivity is a measure of the ability of water to pass an electrical current. It is an index of the total ionic content of the water and is affected by the presence of inorganic dissolved solids anions such as chloride, nitrate, sulfate, and phosphate; or cations such as sodium, magnesium, calcium, iron, and aluminum. It also depends on the temperature and variation in the total dissolved solid in the water (Bhatnagar and Devi, 2013). The desirable range of conductivity in pond fish culture is 100 to 2000 µS/cm; a range of 30 to 5000 µS/cm is however acceptable (Behar and Montpelier, 1997; Stone and Thomforde, 2004). Some aquaculture species, such as channel catfish, can tolerate levels as high as 30,000 µS/cm (Austin et al., 2016).

The mean conductivity in the control ponds was 221.75±81.75 µS/cm (at 25°C) while that of the ponds with water hyacinth was 234.0±134.84 µS/cm (Figure 10). This is similar to the values of 117.3 to 378.4 µS/cm recorded by Keremah et al. (2014) when they analyzed water samples from freshwater fish ponds in Bayelsa State, Nigeria. Total Dissolved Solids (TDS) includes those materials dissolved in the water, such as, bicarbonate, sulphate, phosphate, nitrate, calcium, magnesium, sodium, organic ions, and other ions. These ions are important in sustaining aquatic life. The recommended level of TDS concentration in freshwater aquaculture environment is 500 to 1200 mg/L (Sarkar, 2002; Keremah et al., 2014; PHILMINAQ, 2017). High level of concentrations can result to damage in organism's cell (Mitchell and Stapp, 1996), water

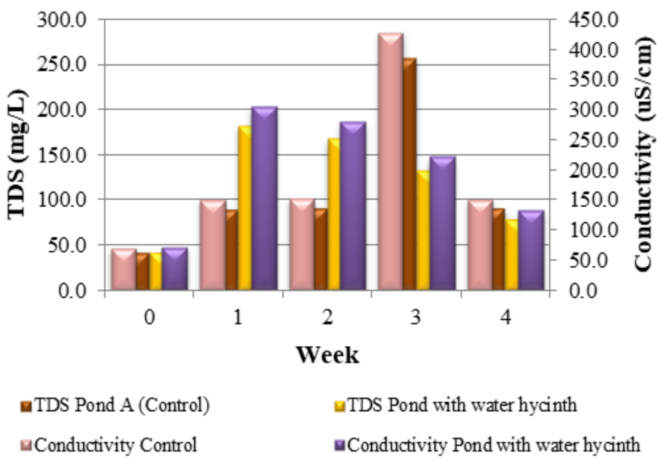

Figure 10. TDS and conductivity values recorded in the ponds during the study.

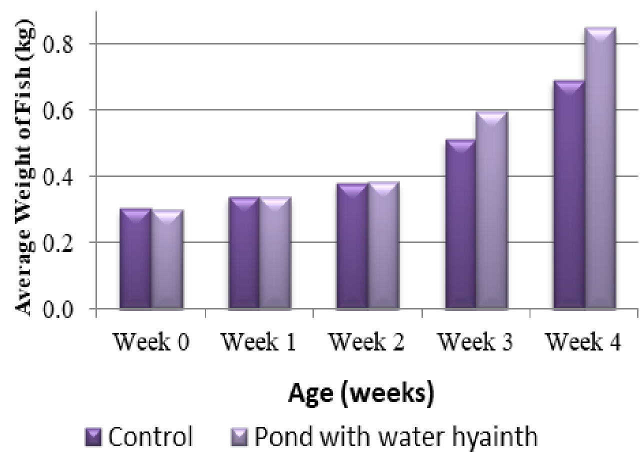

Figure 11. Fish growth rate in pond with and without (Control) water hyacinth (*Eichhornia crassipes)*.

turbidity, reduce photosynthetic activity and increase the water temperature. The mean TDS concentration in the control ponds was 132.5±48.89 mg/L, while that of the pond with water hyacinth was 140.4±81.0 (Figure 10). The dissolved solid contents of both ponds were fairly low. Also, from the graph, it can be seen that there is a clear relationship between TDS and conductivity.

Turbidity

The turbidity in the control ponds ranged from 36.9 to 106.0 NTU with an average of 62.28±31.42 NTU while that of the pond with water hyacinth ranged from 48.8 to 70.0 with an average of 63.7±10.11 NTU. The water in the control ponds was slightly less turbid. Turbidity is a measure of the ability of the water to transmit light. Inability to transmit light may be caused by suspended clay particles, dispersed plankton organisms, particulate organic matter and pigments caused by decomposition of organic matter. Turbidity caused by suspended solids in the water restricts light penetration, limits photosynthesis, and inhibits algal growth and therefore oxygen production. Clay turbidity in water of 30 cm or less may prevent development of planktons blooms (Boyd and Lichtkoppler, 1979). Turbidity range of 30 to 80 cm is good for fish health, 15 to 40 cm is good for intensive culture system, while values less than 12 cm causes stress (Bhatnagar et al., 2004). A value of 30 to 40 cm is considered optimum for a good fish culture (Santhosh and Singh, 2007). Turbidity levels as low as 5 NTU can begin to stress fish within a few hours (VWF, 2017). The turbidity values of the ponds were fairly high.

Growth rate of the fish

There are many factors that impede/facilitates the growth rate of any living organism, catfish is not an exception. Figure 11 shows a comparison of the growth rate of the fishes in the pond with and without (control) the introduction of water hyacinth (*E. crassipes*).

The initial average weight is represented in week 0, while weeks 1 to 4 show their progressive growth rate. At 0 week, the fishes in both ponds had about the same average weight of 0.3 kg. At the end of the first week (Week 1), the average weights of the fish in both ponds were about the same (about 0.34 kg) each. At the end of the second week (Week 2), the average weight of the fish in pond B was slightly greater than that of A. In week 3, the pond B (with water hyacinth) recorded higher growth rate than that of the control ponds. By the 4th week, the growth rate of the fishes in pond B (with water hyacinth), were far higher than that of the control ponds.

The average weights of the fish in Ponds A and B were about 0.69 and 0.85 kg, respectively implying that the use of water hyacinth could lead to larger fish size. This agrees with the study of Velasco and Cortes (2005) who, working with tilapia, observed that increasing plant cover resulted in the production of larger fish. Although the final average weight of the fish in the ponds with water hyacinth was higher than that of the control; the difference was not significant ($P \leq 0.05$) implying that covering some 15% of the surface of fish ponds used for raising African catfish may not be a worthwhile exercise.

Analysis of variance (ANOVA)

Table 3 shows the result of the ANOVA carried out on the experimental result. The table shows that, although there were some differences in some of the parameters monitored in the control ponds and the ponds with water hyacinth, these differences were not significant at 5% α-level ($P < 0.5$).

Table 3. Results of the statistical analyses.

Parameter	Original stream (Mean±SD)	Fish Pond A (without water hyacinth) (Mean±SD)	Fish Pond B (with water hyacinth) (Mean±SD)	F-value	P-value
Temperature	30.80±0.01	30.88±2.90	30.98±2.72	0.003	0.997**
pH	6.80±0.01	7.00±0.47	6.98±0.60	0.115	0.893**
Conductivity	71.60±0.01	221.75±81.71	234.00±134.84	1.848	0.227**
TDS	43.00±0.01	132.95±48.89	140.40±81.00	1.844	0.227**
Turbidity	22.20±0.01	62.28±31.42	63.70±10.11	2.855	0.124**
Sodium	2.24±0.01	3.65±1.23	3.01±1.45	0.877	0.457**
Calcium	4.00±0.01	7.80±5.71	7.20±3.75	0.508	0.622**
Magnesium	6.00±0.01	4.92±4.29	6.95±3.01	0.349	0.717**
Total Hardness	16.00±0.01	44.75±12.61	39.00±15.45	2.076	0.196**
Ca Hardness	10.00±0.01	19.50±14.27	18.00±9.38	0.508	0.622**
Mg Hardness	6.00±0.01	12.75±4.27	21.00±11.83	2.399	0.161**
Total Alkalinity	14.00±0.01	104.50±56.44	103.00±78.12	1.619	0.264**
Chloride	5.00±0.01	8.50±4.04	8.75±6.70	0.403	0.683**
Nitrate	2.60±0.01	8.60±5.63	23.20±17.47	2.456	0.156**
Nitrite	0.05±0.01	0.15±0.27	0.81±1.43	0.644	0.554**
Ammonia	0.50±0.01	16.90±13.46	14.33±11.76	1.383	0.312**
Sulphate	9.00±0.01	17.25±4.57	18.75±5.38	3.139	0.106**
Phosphate	2.02±0.01	2.66±1.14	2.43±0.71	.357	0.712**
Dissolved oxygen	7.20±0.01	2.33±1.81	3.85±3.48	2.398	0.161**
BOD	4.10±0.01	320.83±270.50	264.24±257.50	0.732	0.514**
COD	5.00±0.01	348.50±306.49	346.50±256.52	1.371	0.314**

**The mean difference is not significant at 5% α-level.

Conclusion

From the results, it can be concluded that African catfish raised in fish ponds with 15% of its surface covered with water hyacinth results in greater weight gain when compared with fish raised in similar ponds but without any water hyacinth cover. The gain in weight is however not significantly different ($P \leq 0.05$) from that of catfish raised in ponds without water hyacinth cover, implying that the use of water hyacinth does not give rise to any significant advantage on fish ponds. The mean concentrations of TDS, total hardness, Mg hardness, chloride, nitrate, nitrite, sulphate, conductivity, turbidity, and DO were higher in ponds with 15% water hyacinth cover. Other parameters such as ammonia and BOD were higher in the control pond. There was however no significant difference between the mean values of water quality parameters of fish pond with 15% water hyacinth cover when compared with the one without cover. This again suggests that covering the surface of African catfish pond up to 15% with water hyacinth may not confer any significant advantage on such ponds.

Since the water in the fish pond with water hyacinth was changed every two weeks, while those in the control pond was changed weekly and since there was no significant difference in the performance of the two ponds, it can also be concluded that the use of water hyacinth can give rise to a considerable reduction in the amount of water required for raising African catfish This finding is particularly useful in areas with low water availability.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Animal feeds legislation: Chicken value chain actors practices and predicaments in Uganda

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This study was conducted to assess the effects of absence of a legal framework regulating the animal feeds industry on poultry value chain actor performance and sustainability. The objectives of the study were to identify the key constraints faced by individual farmers, livestock feed manufacturers, and field veterinary personnel; and assess challenges cutting across the industry actors. Data used in the study were collected using formal survey techniques and key informant surveys. Farmers who mix their own feed and those who buy already mixed reported poor quality and seasonal variation in prices as the main constraints associated with feeds. Adulteration of feed was mostly linked to scarcity of crop-based raw materials, namely maize, sunflower, cotton seedcake, and soya bean and those obtained from lakes, such as lake shells and haplochromis (silver fish) whose supply is seasonal in nature. The following findings are unveiled from the study. Intensive commercial poultry is a major source of income especially to female headed households. Long-term investment in housing structures confirms that farmers have a strong resolve to sustain poultry farming as a priority income generation enterprise. Performance, gains, and delivery of services by all value chain actors - farmers, feed manufacturers/ mixers, and field veterinary officers are adversely affected by lack of a regulations and standards as a result of absence of the animal feeds act. It is concluded that innovation platforms that bring together actors would be necessary to lobby government on legislation. This would enhance improved grain drying and bulk storage and put in place trade barriers restricting exportation of primary farm produce especially maize grain/bran. It is recommended that research expedites efforts to develop and promote energy substitutes to maize.

Key words: Innovation platforms, policy, public-private-participation, supply chains.

INTRODUCTION

Commercial chicken layer and broiler producers heavily consume manufactured feeds as compound concentrates or value added bran, cereal or oil seed by-products on a daily basis (NARO-LSRP, 1999). As a result of this, feeds constitute over 70% of the cost of production in chicken enterprises (Louw et al., 2011). According to Frame

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(2008), a chicken will only grow and perform to the extent it receives proper nutrition. Besides, feed quality will affect feed consumption if compromise can cause disease or nutritional deficiencies. The animal feeds policy Ministry of Animal Industry and Fisheries (MAAIF, 2005) was formulated to realize a vision of an animal feeds industry that contributes significantly to improved animal production and productivity, thus improving the welfare of Ugandans and the national economy. The policy is based on the principles of promoting private sector participation, good manufacturing practices, and quality control stimulating a competitive animal feeds industry, providing suitable regulatory institutional framework and infrastructure for delivery of support services. The policy specifically aims at stimulating increased quality feed production and reduction of feed production costs. Although, the objectives and functions of key stakeholders are defined and compliance to national development plans is clearly laid out, while legislation of the act is still lacking. This means that the feeds industry actors are neither regulated nor guided. As a result of incomplete legislation of the animal feed industry actors proliferation of informal (non-branded) feed, manufactures have dominated the feed manufacturing and mixing domains. Such intermediaries operate side by side with branded commercial feed manufacturers, such as Ugachick, Hilltop, and Formula feeds whose manufacturing practices are similarly hitherto not regulated by Act of Parliament. Other feeds supply chain actors notably farmers are hence exposed to risks of adulteration, counterfeits, and disguised labeling. This in turn leads to poor egg and meat yields and huge decline in production volumes that erode potential gains by the various actors in the industry. Apart from farmers who have a producer cooperative, informal feed manufactures and mixers operate in isolation. Since there are no compelling standards, industry licensing conditions and tax regimes, they individually package feeds, make marketing strategies and deal with farmers using various approaches. There is no motivation for horizontal collusion and commonality in standards and addressing common challenges. On the other hand, government has slackened the process of enacting the feed act. One possible cause of this is failure for producers to successfully lobby government. Besides, consumers cannot rise up and challenge government on ensuring that the quality feeds are availed to chicken producers, because local chicken demand is partially met by imports. Consumers would still get fresh chicken even if local production is not supported. The main objective of this study was to assess the constraints faced by key actors in the industry in the wake of absence of a legal framework regulating the industry. Specific objectives of the study were to: identify key constraints faced by individual farmers, feed manufacturers, and the field veterinary personnel; assess challenges cutting across the industry actors due to lack of a networking umbrella organization; and provide information and make recommendations necessary for accelerating the national feeds policy development.

METHODOLOGY

Sampling procedure and data management

Chicken meat value chain consists of several actor, such as farm input provision that include feeds, drugs, and feed ingredient suppliers, chicken farmers, chicken wholesalers, and retail outlets through hoteliers, restaurants, fast foods operators, and road side roasters who prepare fresh dressed whole or pieces of chicken. Similarly, the egg value chain actor stems from feed and feed ingredient suppliers, feed mixers, egg wholesalers, retailers, roadside, restaurant, and fast food operators. Assessment of the system demands sufficient information on challenges faced by individual economic units and stakeholders that may be vertically or horizontally cutting across the value chain actors in the feed industry in Uganda. According to UBOS (2009), the national chicken flock for Uganda is estimated to be 37.4 million in 2008 and the Eastern Region had the highest number of chickens estimated to be 10.7 million (28.6%). Jinja district was selected for the study based on its peri-urban nature, small land holdings, availability of branded feed manufacturing firms, such as Unga Ltd and Hilltop and presence of several commercial broiler and layer chicken units across the district. In total, the district has about 470,000 chickens (UBOS, 2009). Jinja district is located in the Southwestern part of the Eastern region of Uganda. It is made up of three counties, namely Kagoma, Butembe, and Jinja municipality. The bulk of the data used in the study were collected using formal survey techniques based on standard questionnaire and direct interview techniques. These were supplemented by key informant surveys that included expert opinion interviews from the veterinary department, sub-county National Agricultural Advisory Services (NAADS) Coordinators (SNCs) and feed suppliers. A household formal survey was conducted in three divisions of Jinja district, namely Mpumudde/Kimaka, Mafubira and Bugembe. At farm-level, a household was the sampling and analytical unit. Households selected covered variability in terms of proximity to the input and product market/degree of urbanization, diversity and potential crop-livestock integration and degree of public and private veterinary treatment, extension and advisory contact. A household was defined as a group of persons who live in the same dwelling and eat together, often have same principle decision maker(s), and utilize exclusive livelihood resources, such as domestic land. Sampling of households was done using multi-stage, purposive and systematic random techniques. The thrust of this study was feed legislation. Absence of adherence to regulations and standards often make farmers get exposed to vagaries of fake and/or poor feeds on the market. Apart from raising cost of production, such feeds can make farmers incur financial losses through bird stagnation, poor growth, meat and egg productivity performance. To counter these effects and as a sign of lack of confidence in the formal feed supply sector, farmers then mix their own feeds. Commercial layer and broiler farm households tend to operate in a similar fashion when it comes to feed mixing. Majority of the used maize is as the basal energy source, silver fish as the protein component and ingredients like cotton seed cake, lake shells and multi-vitamin pre-mixes to incorporate additional miners and vitamins. Given this nature of homogeneity, a representative sub-sample size of 35 respondents would be sufficient to conducts the descriptive statistics (means, percentages, chi squares, and t-tests) that characterize the bulk of this study. On the basis of sources of poultry feeds, farmers were categorized into those who mix their own feeds (45) and those who buy pre-mixed feeds (35) giving a total sample size of 80 households. Variations in characteristics of household by gender and source of poultry feeds were examined using SPSS Computer Package (Version 16).

Gender was considered to be an important factor because in Uganda women and men in urban and peri-urban areas with formal employment tend to supplement their monthly income and improve home nutrition by keeping egg or broiler commercial units. Unemployed house wives and women in similar localities keep commercial egg and broiler chickens to boost and/or have a steady source of income. Qualitative data were extracted using expert opinion interviews on experiences and constraints in quality and inter-seasonal feed supply, coping mechanisms and potential solutions in the situation of non-existent enforceable policy framework. This was supplemented by physical verification using direct observation of farm and feed production units. In addition, laboratory analysis using Near Infra Red Spectrometry (NIRS) was made on samples of feeds from 12 formal and informal mixers and manufacturers.

RESULTS AND DISCUSSION

Supply chain actors' experiences on feed quality

Key feed related constraints and challenges, main effects. and potential solutions as viewed by feed manufacturers and district field veterinary department are discussed in this section. These findings indicate that risk aversion in relation to poor feed quality, exportation of primary products especially maize grain and bran to neighboring counties, seasonal price changes and distant sources of raw materials are the major challenges faced by feed manufacturers. These conditions affect the performance of commercial chicken firms through premature and unplanned sales whenever maize cost shoot beyond Uganda shillings 1000 (One USD ($) is equivalent to about 3500 Uganda shillings). By so doing the usual economic life span for layers to about seven months instead of eighteen months and stunting of broilers is reduced. Besides, farmers are now turning to intensively rearing of slower growing and less efficient egg producing local birds or crosses. In addition, they opt for mixing their own feeds which may lack some ingredients. This results into incomplete rations. In relation to this, Webster (2005), indicated that hens need a balanced and adequate diet to maintain egg production. Each egg contains significant amounts of protein and energy, which must first be consumed by the hen as part of its daily food intake. Too little dietary energy or an imbalance of amino acids can cause depressed egg production. Where mixing is done by commercial informal feed mixers, farmers often prefer to personally supervise feed mixing to ensure accurate and complete mix of all desired ingredients. In worst extremes, farmers have completely abandoned the poultry business due to prohibitive feed prices. These findings concur with New Vision (2012) who reported that deadly chicken feeds flooding the market by unscrupulous dealers in districts of Mukono, Wakiso, Jinja, Luwero, Mpigi, and Kampala caused farmers loses of million Uganda shillings. They cited an example, a 56% reduction of egg production from 180 to 80 trays a week leading to closure of the multi-million household poultry farming project that was generating more than 4 million Uganda shillings per month in 2011. Government interventions in form of movement controls, prohibitive trade licensing of essential feed and feed ingredient storage and marketing restrictions curtailed exportation of feed ingredients in India (Balakrishnan, 2001).

Findings on challenges faced by the veterinary department indicate that lack of legal backing to resolve conflicts among value chain actors, absence of self-regulating mechanisms among suppliers and lack of feed standards are the key challenges faced by the field vets. These have led to crippling of the veterinary service in enforcement of quality assurances measures, and prosecution of offenders. These have in turn led to distrust of the department by especially afflicted farmers and this is still paralleled by continued proliferation of fake feed dealers. Similarly, New Vision (2012) observed that such problems are bound to persist due to lack of relevant legislation yet policy that would restrain the private sector-led industry from deliberate adulteration. Besides, a matching fine of not exceeding Uganda shillings 480,000 or imprisonment of not more that 12 months provided for in the policy as was passed seven years ago are no longer prohibitive to offenders. Given these challenges, it is logical to suggest that feed standards be established with prohibitive legal instruments and penalties, register and license feed manufacturers, train, regulate and regularly inspect their premises and products they put on market and form self regulating or peer monitoring, learning umbrella bodies. In order to verify farmers' complaints about quality of commercial feeds, a laboratory analysis of commercial poultry layer and broiler feeds by National Livestock Resources Research Institute (NaLIRRI) of National Agricultural Research Organisation confirms that poultry feeds on the market were below the recommended standards. Both broiler and layer feeds were below recommended Crude Protein (CP) and Metabolisable Energy (ME) levels (Figures 1 and 2). The corresponding figures were 17 and 16.1% DM for CP as compared to the recommeded levels of 20 and 17%, for broilers and layers, respectively. A similar trend is observed on ME where about 600 and 400 Kcal/kg DM broilers and layers are deficient on the recommended critical level of 3000 and 2800 Kcal/kg DM for broilers and layers, respectively.

Socio-economic characteristics and household domestic resources

Key chicken enterprises, main sources of livelihoods and contribution of poultry enterprise to cash income

Findings of the study show that 40% of poultry farms are

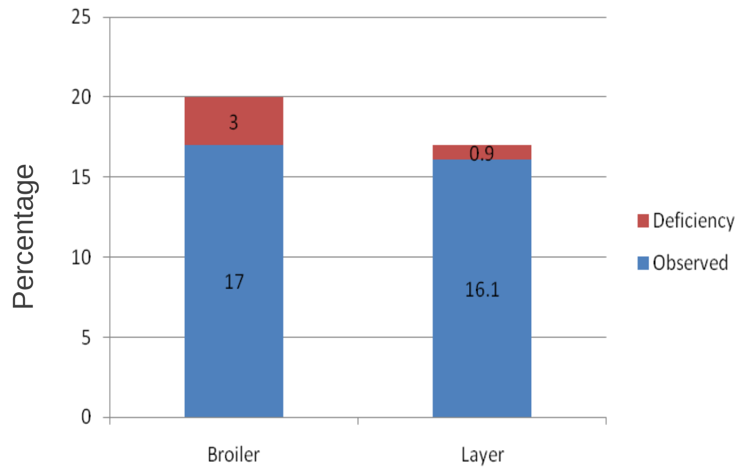

Figure 1. Crude protein (% Dry Matter) content.

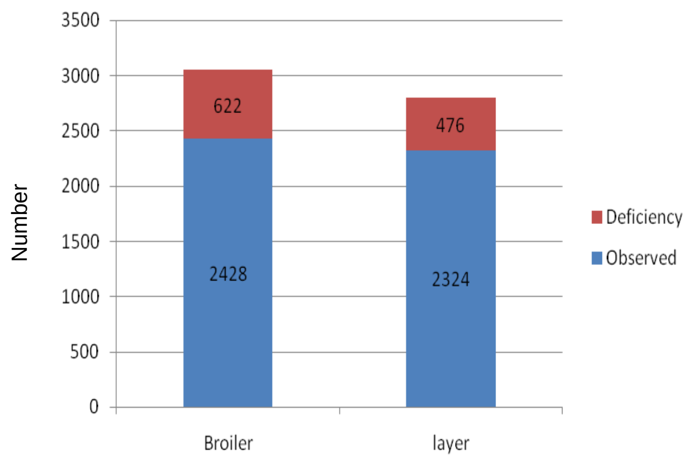

Figure 2. Metabolisable energy (M.E Kcal/Kg DM).

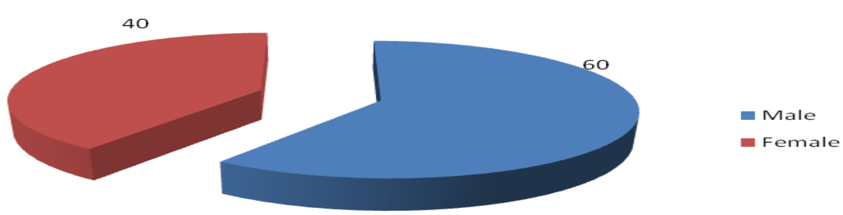

Figure 3. Sex of poultry farm household head.

female headed (Figure 3). Layers were the most common enterprise managed in the area (55%). Broilers were kept by a sizeable (35%) proportion of the female headed households, because of their ability to generate faster returns to investment. According to Ngugi et al., (2002) women played the major role in the management of the chicken and were involved in decisions related to the chicken. Similar to what was observed by key informants, as a risk averting measure, about 6% of the female headed homes intensively kept local chicken and/or crosses whereas about 15% of the households kept a combination of layers and broilers (Table 1).

Similar to Nanyeenya et al. (2013), in the area studied, poultry farming was the major source of livelihood (45%)

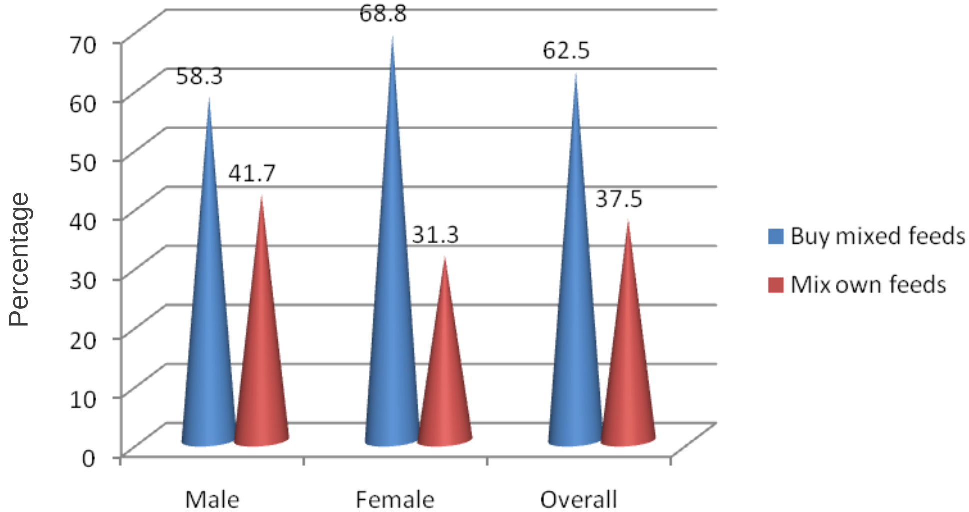

Figure 4. Main source of poultry feeds.

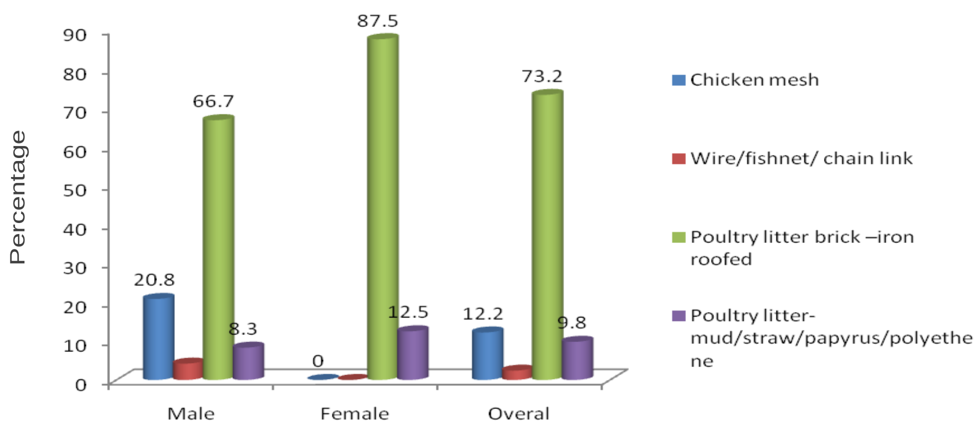

Figure 5. Main housing structures of chickens.

for especially to female headed households (56%). With respect to type of feed used, findings indicate that most (62%) of the households bought mixed feeds from branded and non-branded feed companies. Poultry farming was a main source of cash income for most (61%) of the households, but more so for female headed ones (88%).

Investment in poultry feed, housing and farm labour

Findings of the study on farmers' investment in feeds, housing and farm labour are presented in Figures 4 to 6. A sizeable proportion (38%) of farmers bought ingredients and mixed their own feeds. On the whole (overall), the entire sample 62.5% of the farmers bought mixed feeds. This concurs with Fanatico (2003) who noted that some producers decide to mix their own rations in order to be assured that genuine ingredients and the required proportions are used. Those who mixed their own feeds cited lack of confidence in what has been already been mixed as the major reason for mixing their own feeds. The rest of the famers bought already mixed feeds. Those who buy mixed feed stated that mixing of especially chick mash requires a unique precision and expertise that they lack. This was underscored by Beyer et al., (2001) who confirmed that commercial feed purchased from a reliable dealer, has all the nutrients chickens need to grow and thrive.

There was substantial investment in poultry housing as indicated by majority (74%) of households rearing their flocks in iron-roofed deep litter systems (Figure 5). This is in agreement with Kitalyi (1997) who stated that proper housing that should be constructed using locally available

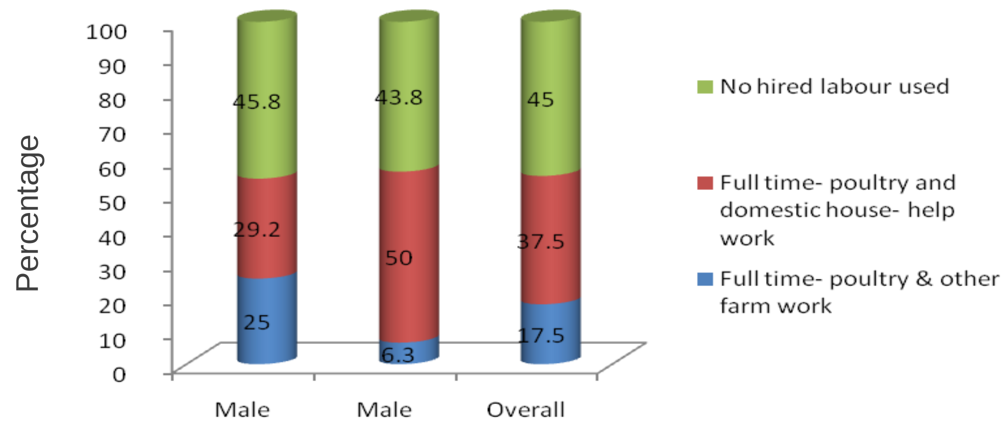

Figure 6. Farm labour types used in poultry management.

Table 1. Distribution of chicken enterprise by sex of household head.

Chicken enterprise type		**Layers only**	**Broilers only**	**Local/crosses**	**Layers and broilers**	
Male		60.9	21.7	0	17.4	
Female		47.1	35.3	5.9	11.8	
Overall		55.0	27.5	2.5	15.0	
Main source of household livelihood	**Crop cultivation**	**Poultry farming**	**Petty trading**	**Odd jobs**	**Formal employment**	**Other**
Male	0	37.5	12.5	8.3	20.8	20.8
Female	12.5	56.3	6.3	0	25.0	0
Overall	5.0	45.0	10.0	5.0	22.5	12.5
Nature of poultry business		**-**	**Side cash income**		**Main cash income**	
Male		-	54.2		45.8	
Female		-	12.5		87.5	
Overall		-	36.6		61.0	

materials to create a favourable environment and guard against snakes, rats, dogs, cats, foxes, and thieves.

It was discovered that majority of the households (45%) relied on family labour, a combination of house-help and poultry management hired workers (37%). Only 18% of households hired farm labour whose exclusive responsibility was poultry management and farm work (Figure 6). This has implications on targeting and effec-tiveness of training that is often skewed towards enterprise owners rather than actual managers and/or family or hired workers.

Socio-economic characteristics of farmers who mix their own feeds and those buying mixed feeds are shown in Table 2. Those who mix their own feeds have significantly larger land sizes where they grow some of the crops used as raw

Table 2. Characteristics of farmers mixing and those buying mixed feeds.

Characteristic	Type of feeds used on the farm				
	Mix own feeds (n= 45)		Do not mix feeds(n =35)		t – test
	Mean	SD	Mean	SD	
Land size	1.83	1.92	1.06	0.83	0.005***
Cattle herd (Number)	2.50	2.12	5.38	3.11	0.451NS
Age oh household head (years)	46.86	10.02	46.87	11.07	0.767NS
Total household size (Number)	7.77	3.00	7.70	3.99	0.314NS
Layer flock size (number)	336.79	163.14	338.05	167.88	0.992NS
Broiler flock size (Number)	291.71	149.84	169.17	136.30	0.532NS
Farming experience (Years)	7.47	4.97	7.08	5.91	0.788NS
Characteristic by sex of household head	**Male headed (n = 48)**		**Female headed (n = 32)**	**Overall**	χ^2
Level of education of household head					
None	8.3		0		
Primary/elementary	0		12.5	11.8	3.37^{NS}
Secondary	34.8		37.5	42.2	
Tertiary	65.2		50.0	47.1	
Business owner (Entrepreneur)					
Wife	29.2		0	17.5	
Male head	16.7		0	10	
Family/other family member	54.2		37.5	47.5	0.001***
Female head	0		50	20	
Group	0		12.5	5	
Group membership & function					
Training	13.6		30.8	20	
Share market information /experiences	22.7		15.4	20	
Savings &Coop. Credit Org. SACCO	0		7.7	2.9	0.429^{NS}
Do not belong to any group	45.5		38.5	42.9	
	18.2		7.7	14.3	

*Denotes significance at 5%, **at 1%, and ***at 0.1%.

materials for feeds, such as maize.

These two farmer typologies were similar in terms of factors like chicken flock size, age of household heads, household size, level of education, poultry farming experince and cattle herd size. There was, however, significant differences between male and female headed households with respect to business ownership. A large proportion of enterprises (50%) among female headed households belonged to the head herself. In male headed households, a more or less corresponding figure (54%) belonged to other family members. With respect to group membership, about 40% of male and female headed households did not belong to farmer

Table 3. Experiences and constraints by farmers mixing and those buying mixed feeds.

Characteristic	Buy mixed feed	Mix own feeds	Overall	χ^2
Main feed related constraints				
Poor quality	40	35.7	38.5	
Distant suppliers	8	0	5.1	
Seasonal variation in prices	48	42.9	46.2	0.292NS
Variations in quality by the same producer	4	7.1	5.1	
Disappearance of inputs from market	0	14.3	5.1	
Location of main source of feed				
Within same village/location	8	26.7	15	
Nearby trading centre	48	13.3	35	0.033**
District town	44	46.7	45	
Other	0	13.3	5	
Manifestation of poor quality				
Moulds	17.4	0	11.1	
Adulteration	56.5	61.5	58.3	3.59NS
Counterfeits/deceptive labeling	0	23.1	8.3	
Incomplete mix of ingredients	26.1	15.4	22.2	
Effects of feed raw material scarcity				
Price hike only	21.7	30.8	25.0	
Price hikes and adulteration	73.9	61.5	69.4	0.733NS
Adulteration, no price changes	4.3	7.7	5.6	
Worst feed related experience	**Poor enterprise performance**	**High feed price grossly eroding affecting profits**	**Stunting leading to early forced sales**	**Other**
Buys mixed feeds	53.8	30.8	0	15.4
Mixes own feed	36.4	36.4	9.1	18.2
Overall	45.8	33.3	4.2	16.7

groups. Producer groups facilitate easier access to inputs, feed supplementation, improved birds, drugs and vaccines, technical advice, access to credit, training, transportation and marketing of poultry products (Aini, 1990 in Branckaert et al., 2000).

Results of seasonality, price, and quality changes in both raw materials and feeds bought by farmers who mix their own feeds and those who buy mixed feeds are shown in Table 3. Irrespective of whether they mix their own feed or buy already mixed feeds, farmers reported poor quality and seasonal variation in prices as the main constraints associated with feeds. This concurs with Ja'afar-Furo and Gabdo (2010) who cited high price of feeds as being the major constraint to poultry production in Nigeria. Besides Branckaert et al., (2000) noted that by identifying and using locally available feed resources can be done to formulate low cost diets that are as balanced as possible. Adulteration of feed was mostly linked to scarcity of raw materials, many of which especially the crop-based such as maize, sunflower, cotton seedcake, and soya bean and lake based ones such as cowrie shells and haplochromis (silver fish). Adulteration of feeds and seasonal price hikes lead to rise in cost of production and closure of some chicken enterprises. Given that chicken meat is preferred livestock meat by all Ugandan cultures, once it losses good quality and affordability possibility of importation of whole chicken that further threaten the already challenged chicken industry fills the gap. Imported chicken from Brazil hit the market at about 8,500 shillings compared to 12, 000 shillings for locally produced birds. It is hence not surprising that farmers cite poor enterprise performance as the worst feed related effect.

CONCLUSIONS AND IMPLICATIONS FOR RESEARCH AND DEVELOPMENT

Risk aversion related to poor feed quality, exportation of primary products especially maize grain and bran to neighboring counties, seasonal price changes, and distant sources of raw materials are the major challenges faced by feed manufacturers. Lack of legal backing to resolve conflicts among value chain actors, absence of self-regulating mechanisms among suppliers and lack of feed standards are the key challenges faced by the field vets. Irrespective of whether they mix their own feed or buy already mixed, farmers reported poor quality and seasonal variation in prices as the main constraints associated with feeds. Adulteration of feed was mostly linked to scarcity of raw materials especially the crop-based such as maize, sunflower, cotton seedcake, and soya bean and lake based such as lake shells and haplochromis (silver fish) that are seasonal in nature. The following conclusions are drawn from the study:

(1) Intensive commercial poultry is a major source of income especially to female headed households
(2) Long-term investment in housing structures confirms that farmers have a strong resolve to sustain poultry farming as a priority income generation enterprise
(3) All actors' farmers, feed manufacturers/mixers and field veterinary officers performance, gains and delivery of services are adversely affected by lack of a regulatory, legal framework that would be provided by an Animal Feeds Act.

It is therefore recommended that the following areas be addressed by research and legislation:

1. Enhance improved grain drying and bulk storage, put in place trade barriers restricting exportation of primary farm produce especially maize grain/bran. Alternatively, research should develop and promote energy substitutes to maize since export of maize grain and bran offer a reliable market to Ugandan maize producers and processors.
2. Parliament should pass the Animal Feeds Act, establish feed standards, together with the relevant prohibitive legal instruments and penalties, and define roles of various stakeholders (veterinary department, farmers, local governments, quality assurance, feed raw materials and input (ingredients) suppliers.
3. Value chain actor business performance will be enhanced by value chain actors forming innovation platforms to address common constraints.

Conflict of Interests

The authors have not declared any conflict of interests

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Full Length Research Paper

No-tillage effect on carbon and microbiological attributes in corn grown in Manaus-AM, Brazil

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The soil is the most important carbon reservoir, but agricultural practices involved in tillage systems decrease the soil carbon stock. This study aims to evaluate the effect of no-tillage (NT) on carbon and microbiological attributes of the soil in corn plantations in Manaus-AM, Brazil. Soil was sampled in a secondary forest (SF) and in corn grown under different tillage systems, including conventional tillage (CT), which makes use of plowing and harrowing operations, and no-tillage (NT). Soil variables studied included, carbon content, soil microbial carbon and basal respiration, metabolic and microbial quotients. The data were analyzed by analysis of variance and Tukey's test. The results demonstrated that NT resulted higher carbon, lower basal respiration, and lower metabolic quotient than CT and SF. However, soil microbial carbon was similar in all tillage systems studied. We conclude that NT corn cropping increased soil carbon content more than CT, while it decreased basal respiration and metabolic quotient when compared to NT and SF. Moreover, soil microbial biomass in corn was similar in all tillage systems studied. This research demonstrated the importance of NT to soil carbon conservation and soil management in corn cropping.

Key words: Tillage systems, land use, microbial soil biomass, basal respiration.

INTRODUCTION

Soil quality is very important for agricultural sustainability and environmental conservation (Khaledian et al., 2016). However, this quality is altered by interferences with the chemical, physical and biological properties of the soil (Cattelan et al., 1990; Andrist-Rangel et al., 2007; Cerdà et al., 2017) caused by the soil management practices

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Figure 1. Sampling areas in a corn plantation.
A No-tillage, B conventional tillage and C secondary forest.

involved in the various tillage systems in use (Treseder, 2008; Lu et al., 2011). Differences in tillage systems are related to soil mobilization and disposal of plant residues (Lisboa et al., 2012).

Conventional tillage (CT) uses plowing operations that change soil structure and reduce soil organic matter and microbial activity (Allaiume et al., 2014). In contrast, no-tillage (NT) minimizes soil disturbance, thereby promoting the increase of carbon and microbial carbon in the soil (Bayer et al., 1997; Pérez et al., 2004). Microbial change is determined by microbial biomass, respiration and metabolic quotients (Tótola and Chaer, 2002; Gajda et al., 2012).

Microbial biomass is the live and active part of the soil organic matter (Tótola and Chaer, 2002). It is also a more evaluable organic matter reservoir (Roscoe et al., 2006). In addition, soil respiration can reflect disturbance and ecosystem productivity (Islam and Weil, 2000); while the microbial quotient was used in studies of soil organic matter dynamics (Tótola and Chaer, 2002). Moreover, tillage affects CO_2 liberation and soil compaction, which may enhance climate change and soil erosion (Bogunovic et al., 2017).

Effects of soil preparation on agricultural crops have scarcely been studied in the state of Amazonas. Thus, the objective of this work is to evaluate the effect of NT on carbon and microbiological attributes of the soil in corn grown in Manaus-AM.

MATERIALS AND METHODS

Soil sampling was carried out in March of 2012 in Ferrosols (WRB, 2014) located in Manaus (2°53'47.27"S, 59°58'29.76"O) Amazonas. Spacing between samples was 10 m and sampling depth was 10 cm. Samples were obtained in secondary forestland and in a corn plantation under either CT with plowing and harrowing operations or under a NT, without soil movement. Ferrosols represent 18.15% of the soils in the state of Amazonas and correspond to 285,041.75 km^2 (Teixeira et al., 2010). These sampling areas are shown in Figure 1. Cultivation of corn under NT was carried out between 2008 and 2012. The crop was fertilized with 425 kg ha^{-1} of 4N-14P-8K at sowing. Additionally, 2 kg ha^{-1} Zn and 90 kg ha^{-1} N were applied by broadcasting. Finally, 1,500 kg.ha^{-1} dolomitic limestone was applied (CFSEMG, 1999).

Soil samples were sieved through a 2 mm mesh prior to chemical analysis according to Claessen et al. (1997). Results are summarized in Table 1. After that, the soil carbon was determined by wet oxidation method (Walkley and Black, 1934). Microbial biomass carbon (MBC) and basal respiration (BR) were evaluated by Infra-Red Gas Analyzer (IRGA) measurements according to Anderson and Domsh (1978). MBC was calculated using the formula below:

$$MBC = (BR \times 40.04) + 0.37$$

Where:

BR = μL CO_2 min^{-1}.g^{-1}.

Other formulas were used for metabolic and microbial quotient respectively:

$$qCO2 = MBC/BR;\ qMic = (\frac{MBC}{Ct}) \times 100$$

The results were subjected to analysis of variance to detect significant effects (Fisher, 1925), while means were compared by Tukey's test (Pimentel-Gomes, 2009). The analysis was done using Matlab software using p<0.05 for Ct, RB and qCO_2, and p<0.10 for CBM and *q*Mic (Table 1).

RESULTS AND DISCUSSION

NT corn and SF showed higher soil carbon concentration

Table 1. Soil analysis in corn plantation areas and secondary forest.

System	pH	P	K	OM	Al	Ca	Mg	H+Al	CEC
	1:1	---mg.dm³---		Percentage (%)	-----------------cmol$_c$/dm³-------------				
Corn NT	5.0	44.7	97.2	4.2	0.6	0.8	0.4	5.1	6.5
Forest	4.6	2.8	15.8	3.8	1.2	0.2	0.1	6.3	6.7
Corn CT	4.7	46.5	93.1	4.2	1.0	0.6	0.3	4.6	5.7

*OM= organic matter, CEC=cation exchange capacity, cmol= centimole, NT= no-tillage, CT= conventional tillage.

Table 2. Soil Carbon (Ct), basal respiration (BR), microbial biomass carbon (MBC), metabolic quotient (qCO_2) and microbial quotient (*q*Mic) in conventional tillage (CT) and no-tillage (NT) corn cropping and secondary forest (SF).

System	Ct (g.kg soil^{-1})*	BR (mg C-CO_2.dia^{-1})*	MBC (mg C.Kg soil^{-1})**	qCO_2 (mg C-CO_2. g^{-1} CBM.h^{-1})*	*q*Mic (%)**
Corn NT	24.4^A	5.4^C	744.9^{AB}	0.3^C	3.0^{AB}
Forest	24.2^A	10.7^B	993.1^A	0.5^B	4.2^A
Corn CT	22.1^B	22.8^A	586.2^B	1.7^A	2.4^B

Means with the same letter within columns do not differ significantly by Tukey's test ($p <0.05$; ** $p <0.10$).

than conventional tillage (CT) corn (Table 2). This higher carbon concentration was due to plant residue accumulation during crop growth (Freixo et al., 2002; Lovato et al., 2004; Sisti et al., 2004; Hickmann and Costa, 2012; Asmann et al., 2014). Furthermore, it could be due to a decrease in mineralization rate (DICK, 1983). Conversely, carbon concentration in SF occurred because of rhizodeposition, fall of leaves and lixiviation (Richter et al., 1999). Rhizodeposition in the forest was affected by plant composition and litter quality (Wilcke and Lilienfein 2004; Wiesmeier et al., 2009). On the other hand, litter quality on the surface of the soil changed due to a high CN ratio and low biodegradability (Tejada et al., 2009) (Table 2).

Basal respiration was lower in NT corn than in the other systems studied (Table 2). These results differed from those observed by D'Andréa et al. (2002) in Goiás, Brazil, where no basal respiration differences between tillage systems for corn production were found. Moreover, the higher basal respiration in the CT corn crop, and SF was due to increased organic matter and nutrients available in the soil (Emmerling et al., 2000).

Microbial biomass carbon (MBC), was higher in SF than in CT corn, but showed no difference with respect to NT corn (Table 2). Higher MBC in SF is related to the higher quantity and quality of plant residues and organic matter quantity (Jacinthe et al., 2000; Fierer et al., 2009; Diacono and Montemurro, 2010). We recorded a decrease in MBC in CT corn, caused by the combined effect of a reduction in carbon input and a decrease in soil carbon stock (Kallenbach and Grandy, 2011). This decrease was also a result of agricultural practices, such as soil plowing and fertilizer use (Treseder, 2008; Lu et al., 2011). Results for NT in this study were different from those obtained in other studies, which showed higher CBM content in NT than in CT corn crops in Paraná state and the Cerrado areas of Brazil (Balota et al., 1998; Balota et al., 2004). However, CBM under NT showed a similar behavior to that observed in Minas Gerais state (Rangel and Silva, 2007).

The qCO_2 was lower for NT than for the other systems (Table 2). The same was observed in other studies on NT in southern Brazil (Balota et al., 2004). The higher qCO_2 in Ct corn may be due to the incorporation of plant residues into the soil (Ocio and Brookes, 1990). Therefore, the differences between NT and CT corn were due to microbial access to the substrate (Alvarez et al., 1995). Soil qCO_2 in CT corn showed an imbalance and was probably dominated by organisms growing faster (Sakamoto and Obo, 1994). Instead, the lower qCO_2 in NT corn and SF occurred due a greater efficiency of the microbial biomass in using environmental resources with lower carbon losses, such as CO_2 (Anderson and Domsch, 1985). Hence, the qCO_2 values in SF and NT corn indicated a greater stability of the microbial biomass in these systems (Santos et al., 2005). The higher qCO_2 value in SF than in NT likely occurred due to the more advanced stage of plant succession (Chapman et al., 2003).

Higher qMic was observed in SF than in CT corn, but it did not differ from qMic registered for NT corn (Table 2). Overall, qMic values measured in this study were higher than values measured in other areas of the Amazon rainforest, where qMic values ranged from 1.1% to 3.7% (Pfenning et al., 1992, Geraldes et al., 1995, Moreira and Malavolta, 2004).

Corn growing areas showed qMic values similar to those found in other Amazonian sites with 2.6% (Pfenning et al., 1992). Differences observed in qMic values in this study may have occurred due to the formation and conversion efficiency of recalcitrant organic matter into microbial biomass carbon (Sparling, 1992). We also observed that qMic values obtained in SF and in corn growing areas were 2.2% higher, which is the suggested value for a balanced soil (Jenkinson and Ladd, 1981).

Conclusions

The no-tillage corn system increased soil carbon content over that registered under the conventional tillage system. Moreover, no-tillage displayed lower basal respiration and metabolic quotient values, compared to conventional tillage and secondary forest. Furthermore, it showed similar microbial biomass to that which characterized these other systems.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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