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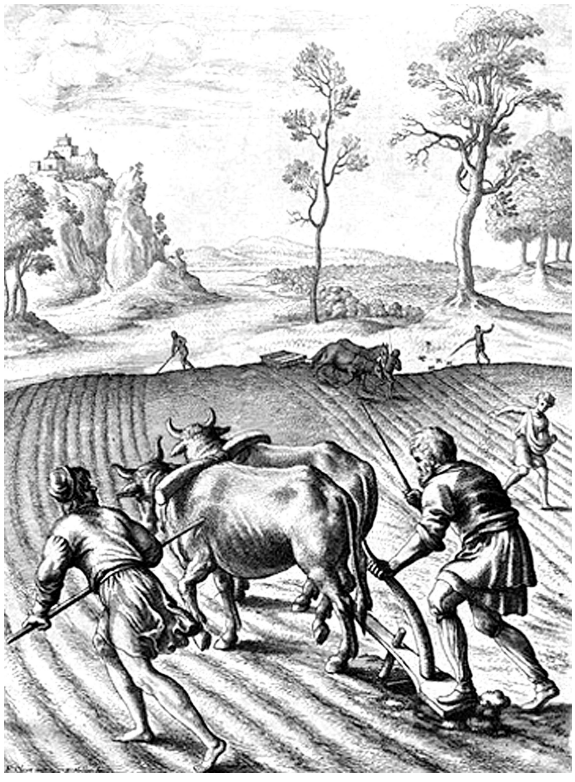

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Influence of Combined Application of Inorganic-N and Organic-P Fertilizers on Growth of Young Tea Plant (*Camellia sinensis* var. *assamica*) in Humid Growing Area of SW Ethiopia

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Abstract: A study was conducted to determine the effect of combined application of inorganic nitrogen and organic phosphorus fertilizers on growth of young tea plant (*Camellia sinensis* var. *assamica*). The field experiment was conducted in Gera district in Southwest (SW) Ethiopia during 2010/2011 and 2011/2012 cropping seasons. We used two fertilizers "Orga" and urea as sources of phosphorus and nitrogen, respectively. We tested four rates of nitrogen (75, 150, 225 and 300 kg N ha^{-1}) combined with a constant rate of phosphorus (30 kg P ha^{-1}) and one unfertilized control treatment. The experiment was laid down in a randomized complete block design with three replications. The results showed that combined application of inorganic nitrogen (urea) and organic P (Orga) significantly ($p<0.01$) enhanced plant height, number of leaves per plant, number of branches per plant, root length, leaf fresh and dry weight and root fresh and dry weight. Among the tested rates, combined application of 150 kg ha^{-1} N and 30 kg ha^{-1} P increased leaf number, plant height and branch number per plant by 164.3, 68.8 and 83.4%, respectively compared to control treatment. In conclusion, the use of inorganic nitrogen (urea) fertilizer at 150 kg N ha^{-1} combined with 30 kg P ha^{-1} (Orga) gave the best result in all assessed yield components variables and could be recommended for the study area for high yield and quality tea cultivation.

Key words: Tea plant, urea, inorganic fertilizer, Orga, organic fertilizer, Ethiopia

INTRODUCTION

The tea beverage is processed from the young tender shoots of *Camellia sinensis* (L.) O. Kuntze and is the second largest drink consumed in the world next to water (Gardner *et al*., 2007; Mondal, 2007; Sharma *et al*., 2007). Tea plant is a perennial evergreen tree that grows upto 30 m if not pruned (Moreda-Pineiro *et al*., 2003) but it is usually pruned and trained as low spreading bush to ensure a maximum crop of young shoots and easy harvesting under cultivation (Willson and Clifford, 1992).

In Ethiopia, tea is mostly grown in the highland dense forest regions and Ethiopian tea is increasingly cherished for its aroma and natural flavors and best quality tea in the world (ITC, 2008). Although, great efforts are underway to have as money small holders out-growers as possible by the government, so far tea is produced and supplied by three private estate farms in Ethiopia (Addisu, 2008). The current annual tea production is estimated to be 5000 tons of black tea from the ca. 2609 ha of land currently under cultivation. As the country has approximately 6,000,000 ha of land suitable for tea production, there is a huge potential to expand the cultivation of tea. Despite of suitable growing condition, the productivity of tea in the country is very low, 3200 kg ha^{-1}, as compared to other tea producing countries (Addisu, 2008). Low productivity among other is largely attributed to poor crop management in the field.

Fertilizer is one of the major agricultural inputs contributing to increased productivity in tea plantation (Bonheure and Willson, 1992). For proper maintenance of the health of tea bushes and subsequent high yield, a well-balanced fertilization scheme is necessary throughout the year (Othieno, 1992; Bonheure and Willson, 1992). Ipinmoroti *et al*. (2001) highlighted that nitrogen, potassium and phosphorous in that orders are three major nutrients required for tea cultivation and should be used in proper proportion (Owuor and Wanyoko, 1996).

Because tea is a leaf crop, nitrogen is probably the key element that promotes vegetative growth, improves shoot succulence, shoot size and leaf size and also reduces flowering and fruit setting (Sarwar *et al*., 2007; Han *et al*., 2008). Likewise, phosphorus stimulates root

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formation and growth (Othieno *et al*., 1997; Sarwar *et al*., 2007). Study in India by Verma (1997) has indicated that production of 1000 kg tea-leaf (dry weight) removes 40-50 kg nitrogen, 7-8 kg phosphorus and 20-25 kg potash. However, the response of nitrogen at any level is dependent on adequate availability of other nutrients in the soil pool (Owuor *et al*., 2001). In Ethiopia, soil based fertilizer recommendation is lacking. Generally, farms use blanket recommendation of fertilizers that has been recommended based on the experiences of other tea producing countries specifically Kenya. Accordingly, the large private estate farms are currently using 100-150 kg N ha^{-1} for young tea plants (Addisu, 2008).

In recent years in Ethiopia, the cost of fertilizers is increasing and this continuous increase of fertilizer price is expected to negatively influence the government plan of engaging resource poor small holders out-growers in tea cultivation. This will call for looking for alternative fertilizer sources that can be affordable to resource poor farmers in one hand and reduce the cost incurred for fertilizer purchase by large private estates farms. Locally available organic fertilizers can be exploited as alternative sources of nutrients in tea cultivation. Organic fertilizers, besides their role as nutrient store and soil fertility enhancer, improve soil structure, stimulate soil biological activity and enhances the solubility of phosphorus applied as fertilizer in the soil and contribute greatly to soil health (Hailu *et al*., 2008; Ipinmoroti *et al*., 2001).

Among the organic fertilizers produced and currently available in Ethiopia, Orga is one. Orga which represents the trade name of this organic fertilizer contains 1% N+23% P_2O_5 and 21% calcium oxide (CaO). It is an organic fertilizer produced from bones, stomach paunch, horns and hooves by the action of phosphate solubilizing bacteria and nitrogen fixing bacteria (Active+) (NAFMAC, 2002). As compared to most organic fertilizers, Orga has higher P content (23% P_2O_5). Unlike other organic fertilizers which are bulky and need higher labor for their application, the application rate of Orga is much reduced owing to its relatively high nutrient contents. Moreover, the price of Orga is lower and this necessitate combine application of Orga and inorganic N-fertilizer in this study (NAFMAC, 2002).

Commercialization and use of Orga fertilizer in crop husbandry is already started in Ethiopia. At the moment, some state owned coffee plantations have started use of Orga as source of P in their organic coffee plots (personal observation). Enhanced yield of carrot due to combined application of Orga and N fertilizer (urea) was reported by Hailu *et al*. (2008). However, much study has not been done with respect to effect of Orga fertilizer on the growth of tea plants in the humid growing areas of Southwest Ethiopia. Therefore, this study aimed to determine the effect of combined application of organic-P (Orga) and inorganic N (urea) on growth of young tea plant under the humid growing condition of SW Ethiopia.

MATERIALS AND METHODS

Description of the study area: The study was conducted in Gera district in SW Ethiopia during 2010/2011 and 2011/2012 cropping seasons. The district is located at about 7°59'N latitude and 36°42'E longitude with altitude ranging from 1200-3000 m.a.s.l. The mean minimum and maximum temperatures are 12-26°C, respectively. The annual minimum and maximum rain fall ranges from1880-2080 mm, respectively.

Experimental materials and design: The tea (*Camellia sinensis* var. *assamica*), cuttings were obtained from local private estate farm (Gummaro Tea Plantation). The cuttings were raised following the recommended practices for one year under nursery condition. The seedlings were transplanted to the permanent field in July 2011 using recommended spacing (120×60 cm). The treatments were designed by combining a constant rate of organic-P fertilizer (30 kg P ha^{-1}) with four levels of inorganic-N fertilizer (75, 150, 225 and 300 kg nitrogen ha^{-1}). Unfertilized plot was used as control. Urea fertilizer was used as source of nitrogen and the local blanket recommendation of 100-150 kg N ha^{-1} was used as a bench mark to set the rates. Organic Orga fertilizer was used as organic P source. Randomized Complete Block Design (RCBD) with three replications were used to set the treatments.

A total of 12 plants per plot were maintained. Full dose of phosphorus fertilizer was applied at the start of the experiment while nitrogen was applied in two split. Fertilizer was applied to each young tea plant in ring application. Other pertinent agronomic practices required for tea cultivation were also followed uniformly. The growth of the tea plant was monitored for one year in the field.

Soil sampling and analysis: Pre-planting bulk of surface soil samples (plough depth) were collected at 0-40 cm and analyzed for Total Nitrogen (TN), Organic Carbon (OC), Organic Matter Contents (OMC), Phosphorous (P), pH, potassium (K) contents and texture at soil laboratory of Jimma University, Ethiopia.

Response variables assessed: Plant height, leaf length, number of leaves per plant, number of branches per plant, root length, fresh and dry leaf weight per plant and fresh and dry root weight per plant were assessed from four randomly selected plants per plot.

Statistical analysis: First, data was checked for ANOVA assumptions. Data fulfilled all the ANOVA assumptions. Then data was subjected to Analysis of Variance (ANOVA) using SAS statistical software (version 9.2). We also performed Pearson correlation analysis to detect the association among the yield component variables. Least Significant Difference (LSD) was used for the mean separations of the significant variables at 5% significant level.

RESULTS AND DISCUSSION

The soil type of the experimental site was found to be Mollic Nitisols and the soil texture was sandy clay with acidic pH (4.91). The pH of the study site was within the optimum for tea because tea plant prefers deep acidic soils having pH below 5.6 (Othieno, 1992). The organic matter content of the experimental site was 5.21%. The organic carbon of 3.02% was close to the 3.0% ideal for suitable soil for tea cultivation. However, the soil N content of 2.0 g kg^{-1} was very low compared to the critical value of 3.4 g kg^{-1} (Othieno, 1992). Likewise, the phosphorus content of 6.45 g kg^{-1} was still low. The available K content of the experimental site was 0.43 mg kg^{-1}. Generally, the low nitrogen and phosphorus content of the experimental site indicated the need for fertilization for optimum growth and performance of tea plant in the study area.

Leaf length, plant height, leaf number and branch number per plant: There was no significant difference among treatments in terms of leaf length ($p>0.05$). Plant height was significantly affected by combined application of organic-P and inorganic nitrogen fertilizers. Application of 150 kg N ha^{-1} combined with 30 kg P ha^{-1} gave significantly higher plant height than the rest of the treatments (Table 1). There was no significant difference between higher rates of nitrogen fertilizer (urea) (225 and 300 kg N ha^{-1}) combined with constant rate of organic P fertilizer (Orga) at 30 kg P ha^{-1}. Control treatment showed the lowest plant height and significantly different from all treatments.

Treatments effect was significant for number of leaves per plant ($p<0.01$). The minimum number of leaves was recorded from unfertilized (control) while the maximum number was obtained from combined application of 150+30 kg ha^{-1} N (urea) and P (Orga), respectively (Table 1). Application of 150+30 kg ha^{-1} N (urea) and P (Orga), respectively increased growth of leaves by 164.3% compared to the unfertilized control treatment. The application of 225+30 and 300+30 kg ha^{-1} of urea and Orga, respectively did not show any further increase in the number of leaf per plant suggesting growth and quality of a crop can increase until certain limit (optimum rate) and increasing rate of fertilizers applied beyond the optimum requirement will not result in increased quantity and quality (Owuor and Othieno, 1996; Ipinmoroti *et al*., 2001).

The number of branches per plant was significantly affected by different rates of inorganic nitrogen fertilizer combined with organic-P fertilizers (Table 1). The maximum number of branches per plant was obtained from application of 150+30 and 225+30 kg ha^{-1} of urea and Orga, respectively while the least number of branches per plants were recorded from control plot. Among the tested rates, application of 150 kg N ha^{-1} combined with 30 kg P ha^{-1} increased the branches of young tea plant by 83.4% compared to the control treatment. However, there was no significant variation between plots fertilized with 150 and 225 kg N ha^{-1} combined with 30 kg P ha^{-1} in terms of number of branches per plant. Generally, application of inorganic nitrogen fertilizer (urea) combined with organic phosphorus fertilizer (Orga) had significantly increased plant height, leaf number per plant and number of branch per plant in this study. This could be explained by enhanced vegetative growth of young tea plant with increased nitrogen fertilization as N and P play significant role in promoting the vegetative growth of plants by enhancing increased cell division and elongation (Owuor *et al*., 2008, 2010; Qamar-uz-Zaman *et al*., 2011). Our findings corroborate with the study of Ipinmoroti *et al*. (2001) who reported enhanced growth and leaf quality of young tea fertilized with organic and inorganic based fertilization in Nigeria. Sarwar *et al*. (2007)

Table 1: Effect of combined application of organic P (Orga) and inorganic N (urea) on plant height (cm), number of leaf per plant (NL) and number of branches per plant (NB) of young tea plant under field condition

Fertilizer rate [Urea (N)+Orga (P) kg ha^{-1}]	Plant height	NL	NB
(0+0)	40.93^{c}	27.87^{d}	6.53^{c}
(75+30)	51.20^{b}	47.93^{c}	9.87^{b}
(150+30)	69.13^{a}	73.66^{a}	11.57^{a}
(225+30)	59.30^{b}	64.60^{b}	11.60^{a}
(300+30)	58.47^{b}	62.43^{b}	9.60^{b}
LSD at 0.05%	8.89	8.00	1.69
CV (%)	8.46	7.67	9.12

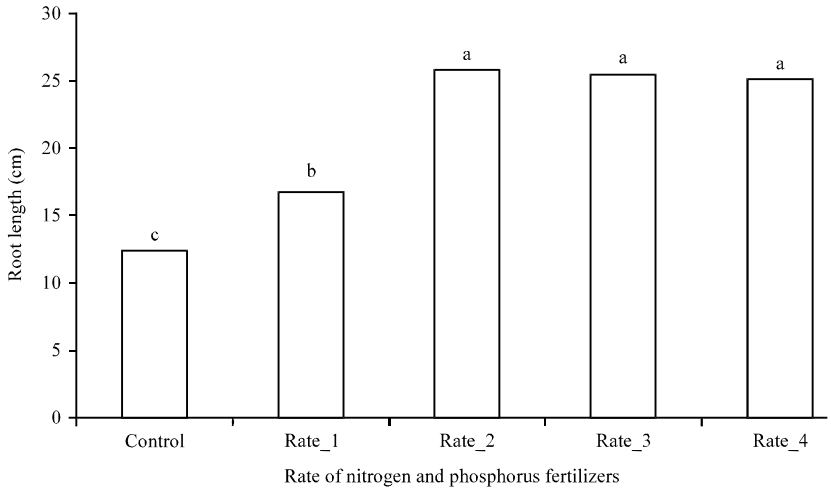

Fig. 1: Root length of young tea plants as affected by different rates of inorganic nitrogen fertilizer (urea) combined with organic phosphorus fertilizer (Orga). Bars capped with the same letter are not significantly different ($p<0.05$). Rate_1: 75 kg N ha^{-1}+30 kg P ha^{-1}, Rate_2: 150 kg N ha^{-1}+30 kg P ha^{-1}, Rate_3: 225 kg N ha^{-1}+30 kg P ha^{-1}, Rate_4: 300 kg N ha^{-1}+30 kg P ha^{-1}

also reported that application of inorganic nitrogen fertilizers supplied the essential nutrient during the growth stage of the plant resulting in increased growth variables. Among others, tea yield is primarily determined by shoot numbers, shoot weight and shoot growth rate (Carr and Stephens, 1992).

Root length per plant: Statistically significant effect of different rates of nitrogen fertilizer combined with constant rate of organic P fertilizer application on root length was evident (Fig. 1).

Our result showed that higher rates (150, 225 and 300 kg N ha^{-1}) of application gave longer root without significant difference among them. These higher rates increased root length of young tea plant by 108.2% compared to control treatment. The poor performance of control treatment could be attributed to the low soil nutrient content of the experimental site. Our soil analysis, indeed, showed that the nitrogen, phosphorus and potassium contents of the experimental site were far below the critical concentration required by the tea plants. Growing crops under marginal soil condition often resulted in stunted growth. Similar findings were reported by other workers (Owuor, 2001; Venkatesan *et al*., 2005, 2006).

Harvestable leaf fresh and dry weight per plant: For harvestable leaf fresh and dry weight per plant, the effect of different rates of nitrogen fertilizer (urea) combined with organic P fertilizer (Orga) was significant (Fig. 2). Accordingly, the highest harvestable leaf fresh and dry weight were recorded on plots fertilized with 150+30 kg ha^{-1} N (urea) and P (Orga), respectively. Control treatment gave the lowest value for both variables (Fig. 2a, b). Application of urea at 150 kg N combined with Orga at 30 kg P ha^{-1} increased leaf fresh and dry content by 77.75 and 119.73%, respectively compared to unfertilized control. The increased harvestable fresh and dry weight could be attributed to enhanced soil fertility following optimum application of nitrogen fertilizer (urea) and improved structural and biological soil condition following application of organic fertilizers on the one hand and relatively higher OM% of the experimental soil. Fertilizers increase leaf yields of tea plant through increased growth rate and density of harvested shoots (Kamau *et al*., 2008; Owuor *et al*., 2008). According to Othieno (1983), the yield (leaf yield) of young tea plant increase with phophatic fertilizer application. However, excessive application of nitrogenous fertilizer often reduces the quality of made tea as color of black tea decrease with increased rate of N (Owuor and Othieno, 1996; Owuor *et al*., 2000; Kigalu, 2007). On the other hand, low rate of nitrogenous fertilizers reported to increase black tea quality but reduce yield production (Venkatesan and Ganapathy, 2004; Venkatesan *et al*., 2004). Application of nitrogen fertilizer (urea) beyond 150 kg N ha^{-1} reduced most of the growth response variables assessed in this study instead of enhancing them.

Root fresh and dry weight per plant: Root fresh and dry weight per plant was significantly affected by different

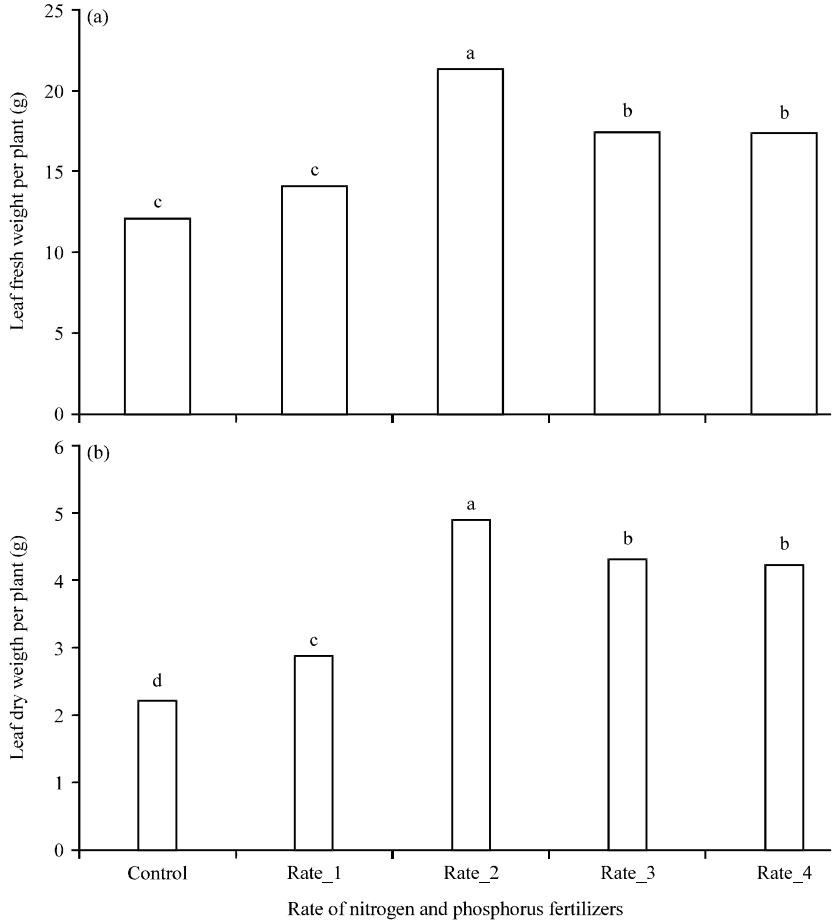

Fig. 2(a-b): Influence of different rates of inorganic nitrogen fertilizer (urea) combined with organic phosphorus fertilizer (Orga) on harvestable leaf (a) Fresh weight per plant and (b) Dry weight per plant of young tea plant under the field. Bars capped with the same letter are not significantly different ($p<0.05$). Rate_1: 75 kg N ha^{-1}+30 kg P ha^{-1}, Rate_2: 150 kg N ha^{-1}+30 kg P ha^{-1}, Rate_3: 225 kg N ha^{-1}+30 kg P ha^{-1}, Rate_4: 300 kg N ha^{-1}+30 kg P ha^{-1}

rates of nitrogen fertilizer (urea) combined with constant rate of organic P fertilizer (Orga) (Fig. 3). The highest root fresh and dry weight per plant was obtained by application of 150 kg N ha^{-1} combined with 30 kg P ha^{-1}. Application of urea at 150 kg N combined with Orga at 30 kg P ha^{-1} increased root fresh and dry content by 82.88 and 66.4%, respectively compared to the control treatment. This could be explained by enhanced soil nutrient content and soil structure following application of both inorganic and organic fertilizers. Application of organic fertilizers often increases the soil structure and the soil physical properties thereby enhance root development (Ipinmoroti *et al.*, 2001).

Correlation among yield component variables: The association among yield components variables were computed and presented in Table 2. Plant height had significant positive association with number of leaves per plant (r = 0.83**), number of branches per plant (r = 0.75**), root length (r = 0.83**), shoot fresh weight (r = 0.90**), root fresh weight (r = 0.93**), dry shoot weight (r = 0.89**) and dry root weight (r = 0.87**). There was also significant and positive correlation between number of leaves per plant with number of branches per plant (r = 0.82**), root length (r = 0.87**), leaf fresh weight (r = 0.63*), root fresh weight (r = 0.85**), leaf dry weight (r = 0.90**) and root dry weight (r = 0.89**). Moreover, number of branches per plant was positively and significantly correlated with root length (r = 0.74**), leaf fresh weight (r = 0.55*), root fresh weight (r = 0.83**), leaf dry weight (r = 0.77**) and root dry weight (r = 0.79**). Furthermore, root length was significantly

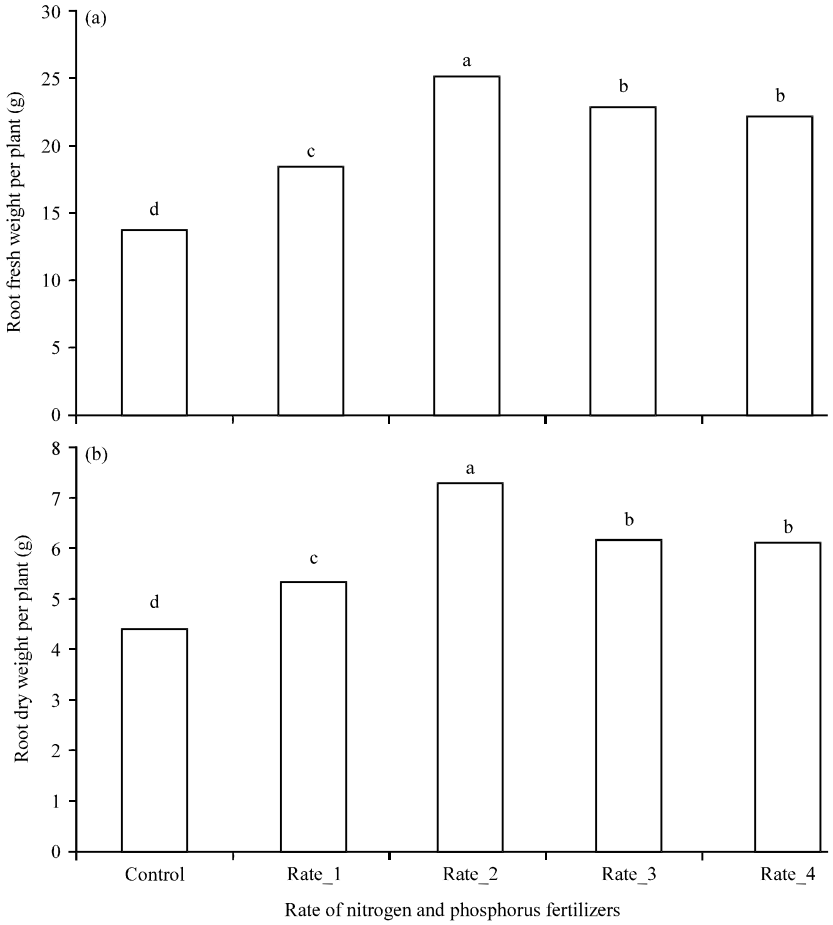

Fig. 3(a-b): Effect of different rates of inorganic nitrogen fertilizer combined with organic phosphorus fertilizer on root (a) Fresh weight per plant and (b) Root dry weight per plant of young tea plant under the field. Bars with the same letter indicate none significant differences ($p<0.05$). Rate_1: 75 kg N ha^{-1}+30 kg P ha^{-1}, Rate_2: 150 kg N ha^{-1}+30 kg P ha^{-1}, Rate_3: 225 kg N ha^{-1}+30 kg P ha^{-1}, Rate_4: 300 kg N ha^{-1}+30 kg P ha^{-1}

Table 2: Pearson correlation among growth variables of young tea in Gera district SW Ethiopia

	LL	PH	NL	NB	RL	LFW	RFW	LDW	RDW
LL	-								
PH	0.41ns	-							
NL	0.57ns	0.83**	-						
NB	0.35ns	0.75**	0.82**	-					
RL	0.50ns	0.83**	0.87**	0.74*	-				
LFW	0.24ns	0.90**	0.63*	0.55*	0.76**	-			
RFW	0.48ns	0.93**	0.85**	0.83**	0.93**	0.83**	-		
LDW	0.53*	0.89**	0.90**	0.77**	0.96**	0.81**	0.96**	-	
RDW	0.54*	0.87**	0.89**	0.79**	0.88**	0.77**	0.92**	0.93**	-

ns: Non significant, **,*Correlation significant at 1 and 5% level of significance, LL: Leaf length, PH: Plant height, NL: No. of leaves per plant, NB: No. of branches per plant, RL: Root length, LFW: Leaf fresh weight, RFW: Root fresh weight, LDW: Leaf dry weight, RDW: Root dry weight

and positively correlated with leaf fresh weight (r = 0.76**), root fresh weight (r = 0.93**), leaf dry weight (r = 0.96**) and root dry weight (r = 0.88**). Finally, leaf fresh weight was significantly and positively correlated with root fresh weight (r = 0.83**), leaf dry weight (r = 0.81**) and root dry weight (0.77**).

CONCLUSION

The study clearly showed that the height, number of leaves per plant, number of branches per plant, root length, fresh leaf and root weight and dry leaf and root weight of young tea plant were significantly affected by

combined application of organic P (Orga) and inorganic N (urea) fertilizers indicating the soils of the study area require application of fertilizers for better and sustainable production and supply of tea. The use of inorganic nitrogen (urea) fertilizer at 150 kg N ha^{-1} combined with 30 kg P ha^{-1} (Orga) gave the best results in all assessed yield component variables and could be recommended for the study area for high yield and quality tea cultivation. We suggest further evaluation of Orga fertilizer with different rates of nitrogenous (urea) fertilizer in over different seasons and tea growing agro-ecologies of the country to establish sound fertilization system for the crop.

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