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Full Length Research Paper

Traits association and path coefficient analysis of yield and related traits in rainfed lowland rice (*Oryza sativa* L.) genotypes in North Western Ethiopia

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The current study was conducted to assess the trait association and path analyses in thirty-six rain fed lowland rice genotypes at two locations. The aim of this present study was to estimate the extent of association between pairs of characters at phenotypic and genotypic levels and thereby compare the direct and indirect effects of the characters. The field experiment was laid out in 6x6 simple lattice design with two replications during 2015/16 cropping season. Thirteen characters were measured including yield and related traits. The extent of phenotypic correlation coefficient values indicated presence of fairly strong inherent association among the studied traits. Moreover, association analyses studies indicated yield had significantly (p<0.05) positive genotypic correlation with days to heading, days to maturity, filled grains per panicle, fertile tillers per plant harvest index, total spikelets per panicle and biomass yield. Path coefficient analyses revealed that biomass yield followed by harvest index, total spikelets per panicle and plant height exhibited the highest direct effects on grain yield; these traits can be considered for direct selection for grain yield of rice.

Key words: Direct effect, indirect effect, path analysis, ground combat vehicle (GCV), packed cell volume (PCV).

INTRODUCTION

The major cultivated species of rice, *Oryza sativa* (2n=2x=24), originated in Southern and South Western Tropical Asia. The other species of cultivated rice, *Oryza glaberrima* (2n=2x=24) is indigenous to the upper valley of the Niger River and it is cultivated only in Western Tropical Africa (Ansari et al., 2015). Rice provides the two-thirds of calories intake for more than three billion people in Asia and one-third of calories intake of nearly 1.5 billion people in Africa and Latin America (Khan et al., 2015).

In Ethiopia, rice is A source of income and employment opportunities for rice farmers. It is used in the preparation of local foods such as *injera*, *dabbo*, *geniffo*, *kinchie*, *shorb* and local beverage like *tela* and *arki* (Gebrekidan

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and Seyoum, 2006; Asefa et al., 2011). Rice production in Ethiopia is predominantly constrained by biotic stress like termite, blast, brown spot diseases, and weeds; abiotic stress such as cold, drought, salinity and soil acidity are the major problems for production of rice. In addition, shortage of adapted varieties to different agro-ecologies and lack of recommended crop management practices for different rice ecosystem (MoARD, 2010; NRRDSE, 2009; Lakew et al*.,* 2014), lack of awareness on its utilization, inadequate technology promotion and seed supply, skilled manpower, erratic rainfall, flood and rice seed shattering was observed (Meron, 2016).

Rice consumers are increasing at the rate of 1.8% every year (Puhan and Siddiq, 2013). The world population is increasing day by day and by 2050 it is expected to reach 9.1 billion; however, agricultural production and productivity is not yet getting higher at a parallel pace (Wani and Sah, 2014). According to an estimate, there are approximately 925 million people on the globe who live in a state of hunger (Karimizadeh et al., 2011). In a bid to eradicate that ugly spot of hunger from the beautiful face of the humanity, we need to significantly increase the production and supply of food by integrating different elements and strengthening the plant breeding tools for crop improvements (Beddington et al., 2012).

Knowledge on association of crop trait for yield with other related traits are essential to the breeder for making crop improvement in a complex quantitative trait such as yield and for which trait direct selection is not much effective. Hence, association analysis is important for determining the direction of selection and number of traits to be considered in improving grain yield (Idris et al., 2012). Path coefficient analysis is a standardized partial regression coefficient and as such measures the direct and indirect effect for one variable upon another and permits the separation of the correlation coefficient into components of direct and indirect effect (Dewey and Lu, 1959). Since yield is a complex trait, indirect selection through correlated is less complex and easier measurable traits would be an advisable strategy to increase the yield. Efficiency of indirect selection depends on the magnitude of correlations between yield and target yield component traits (Bhatti et al., 2005). Breeding strategy in rice mainly depends upon the degree of associated traits as well as its magnitude and nature of variation (Zahid et al., 2006).

Rice breeders are interested in developing cultivars with improved yield and other desirable agronomic traits. In agriculture, path analysis has been used by plant breeders to assist in identifying traits that are useful as selection criteria to improve yield (Dewey and Lu, 1959; Milligan et al., 1990). However, information about trait association between yield and related traits in lowland rice improvement program is not yet well studied. Therefore, in view of this gap, the present study was carried out to evaluate the association between yield and related traits with the objective of estimating the extent of association between pairs of traits at genotypic and phenotypic levels and thereby comparing the direct and indirect effects of the traits.

MATERIALS AND METHODS

Description of the study areas

The experiment was conducted in 2015/16 cropping season at Pawe Agricultural Research Center and Fogera National Rice Research and Training Center. The locations are situated in North Western part of Ethiopia in Benishangual-Gumuz and Amhara Regional States, respectively.

Fogera National Research and Training Center is located 607 km from Addis Ababa in the North Western part of Ethiopia. Particularly, the experimental site is located at 11° 58'N latitude, 37° 41'E longitude and at elevation of 1810 m above sea level. Based on ten years average meteorological data, the annual rainfall, mean annual minimum and maximum temperatures are 1300 mm, 11.5°C, respectively. The soil type is black (Vertisol) with average pH of 5.90.

Pawe Agricultural Research Center is located 578 km away from Addis Ababa. The experimental site is found at 13° 19’ N latitude, 37° 24’ E longitude and at an elevation of 1200 m above sea level. The major soil type of the study site is well drained Nitisol with the pH value ranging from 5.3 to 5.5. The annual rainfall, mean annual minimum and maximum temperatures are 1587 mm, 16.3°C and 32.6°C, respectively.

Experimental materials, design and trial management

The present study contained a total of thirty-six rice genotypes including two checks (Ediget and X-jigna). All rice genotypes were obtained from Fogera National Rice Research and Training Center and were introduced from Africa Rice. The experiment was laid out in 6x6 simple lattice design at each location. The plot size was six rows of 5 m length with 0.2 m row spacing giving a total area of 6 m^2 spacing of 1.0 m and 0.30 m were used between blocks and plots, respectively. For data collection, the middle four rows were used for determination of yield and yield component traits. The genotypes were planted by manual drilling at a rate of 36 g per plot in 2015/16 cropping season at two locations. Recommended fertilizer of Urea and DAP at the rate of 64 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} was applied to each experimental plot. P_2O_5 was applied all at planting time while N was applied in three splits (1/3 at planting, 1/3 at tillering and the remaining 1/3 at panicle initiation) according to the national rice fertilizer blanket recommendation at each location. Weeding was done by hand two to three times starting from 25-30 days after sowing depending on infestation level. All other important agronomic practices were applied as per the recommendation for rice production in the two locations during the growing season.

Data collection

14 quantitative traits of morphological data at right growth stage of rice were collected and recorded according to two rice descriptors (IRRI, 2002; Bioversity International, 2007). Days to 50% heading, fertile tillers per plant, plant height (cm), Panicle length (cm) culm length (cm), flag leaf length (cm), number of filled grains per panicle, number of unfilled grains per panicle, number of total spikelets per panicle, days to 85% maturity, biomass yield per plot (gram per plot) grain yield per plot (gram) thousand grains weight

(g) and harvest index (%) were collected.

Data analysis

Path analysis, phenotypic and genotypic correlations data was subjected to analysis using SAS 9.2 (SAS, 2008) and GENRES Statistical Software, 1994).

Correlation coefficient analysis

Genotypic coefficient of correlation (r_g) and phenotypic coefficient of correlation (r_p) were computed as per Robinson et al. (1955).

$$r_g = Covg(X.Y) / \sqrt{Var\ gX}.\sqrt{Var\ gY}$$

Where, Covg (XY) is genotypic covariance between characters X and Y; Var gX is genotypic variance of character X; Var gY is genotypic variance of character Y.

$$r_p = Covp(X.Y) / \sqrt{VarpX}.\sqrt{VarpY}$$

Where, Covp(XY) is phenotypic covariance between characters X and Y; Var pX is phenotypic variance of character X; Var pY is phenotypic variance of character Y.

Estimates of genotypic and phenotypic correlation coefficients were compared against r-values given in Fisher and Yates (1967) table at g-2 degrees of freedom, at the probability levels of 0.05 and 0.01 to test their significance, where g is the number of genotypes. To test the significance of correlation coefficients, the following formula was adopted (Sharma, 1998):

$$t\text{na} = \frac{\text{r}}{\text{ser}}, \quad \text{sre} = \sqrt{\frac{1-\text{r}^2}{\text{n}-2}}$$

Where, r is correlation coefficient; n is number of characters. To test the significance of correlation coefficient, the calculated t-value can be compared with tabulated t-value at (n-2) degree of freedom at 5% and 1% levels of probability (Snedecor and Cochran, 1981).

Path coefficient analysis

The measure of direct and indirect effects of each trait on grain yield was estimated using a standardized partial regression coefficient known as path coefficient analysis, as suggested by Dewey and Lu (1959). Therefore, correlation coefficient of different characters with grain yield was partitioned into direct and indirect effects adopting the following formula:

$$\text{riy} = \text{r1ip2} + \cdots \text{r1ipi} \ldots + \text{rnipn}$$

Where, riy=is correlation of i^{th} character with grain yield; r1ip2 is indirect effect of i^{th} character on grain yield through first character; rni is correlation between nth character and i^{th} character is the number of independent variables; pi is direct effect of i^{th} character on grain yield; pn is direct effects of character on yield.

The direct effects of different characters on grain yield were obtained by solving the following equations:

$$(\text{riy}) = (\text{Pi})\ (\text{rij});\ \text{and}\ (\text{Pi}) - 1\ (\text{r1iPi})$$

Where, (Pi) is matrix of direct effect; (rij) is matrix of correlation coefficients among all the n^{th} component characters (riy) is matrix of correlation of all component characters with grain yield; (r1iPi) is indirect effect of i^{th} character on grain yield through first character.

The contribution of the remaining unknown factors was measured as the residual factor R, which was calculated as given in Dewey and Lu (1959).

$$R = \sqrt{(1 - \sum rik.pkj)}$$

The analysis was based on all yield contributed traits influencing yield. The estimated values were compared with table values of the correlation coefficient to test the significance of the correlation coefficient prescribed by Fisher and Yates (1967).

RESULTS AND DISCUSSION

Analysis of variance

The analysis of variance revealed that there were significant differences ($P < 0.01$) among thirty-six genotypes for all characters studied at two locations. However, number of filled spikelets per panicle, fertile tillers per plant, number of total spikelets per panicle and harvest index were non-significant at Pawe location while number of unfilled spikelets per panicle ($p < 0.05$) was significant at Fogera location. Though, unfilled spikelets per panicle and thousand grains weight were non-significant at both locations.

Character association

Phenotypic (rp) and genotypic (rg) correlation estimates between the various characters are presented in Table 1. Close values of genotypic and phenotypic correlations were observed between some traits combinations, such as days to heading with plant height, culm length with biomass yield, panicle length with flag leaf length, culm length with filled grains per panicle, biomass yield with harvest index and plant height with panicle length which might be due to reduction in environmental variance to minor proportions as reported by Dewey and Lu (1959). Yield exhibited positive and highly significant ($p<0.01$) genotypic correlation with days to heading (rg=0.678**), days to maturity (r_g=0.803**), filled grains per panicle (r_g=0.523**), fertile tillers per plant (r_g=0.702**), harvest index (r_g=0.668**), total spikelets per panicle (r_g=0.501**) and biomass yield per plot (r_g = 0.730**), respectively which shows that improving these traits may result in the improvement of yield as the results of positive and strong correlation (Table 1). Similarly, Iftekharuddaula et al. (2002) reported the positive correlation of grain yield with panicle length and harvest index. Moreover, days to heading (r_g= 0.532**), days to maturity (rg=0.471**), fertile tillers per plant (r_g=0.314*), total spikelets per panicle (r_p=0.382*), biomass yield (r_p=0.654**) and harvest index (r_p=0.430**) showed positive and significant

Table 1. Estimates of genotypic (r_g) above diagonal and phenotypic (r_p) correlation coefficients below diagonal for fourteen traits of thirty-six genotypes studied at two locations during 2015/16 main cropping season.

Traits	DH	DM	PH	PL	CL	FLL	FGP	UGP	FTP	TGP	BY	TGW	HI	GY
DH	**1**	0.930**	-0.098	0.509**	-0.138	0.195	0.614**	0.396*	0.281	0.588**	0.731**	-0.305	-0.083	0.678**
DM	0.747**	**1**	-0.075	0.446**	-0.116	0.186	0.459**	0.154	-0.001	0.431**	0.756**	-0.099	0.067	0.803**
PH	-0.089	-0.063	**1**	0.450**	0.997**	0.783**	0.076	-0.402*	-0.311	0.053	0.337*	0.680**	-0.702**	-0.145^{ns}
PL	0.356*	0.277	0.403*	**1**	0.369*	0.511**	0.503**	0.500**	0.292	0.524**	0.729**	-0.061	-0.439**	0.415*
CL	-0.127	-0.095	0.995**	0.333*	**1**	0.756**	0.043	-0.453**	-0.362*	0.019	0.300	0.685**	-0.695**	-0.178^{ns}
FLL	0.115	0.104	0.687**	0.539**	0.656**	**1**	0.319	-0.029	-0.347*	0.309	0.411*	0.497**	-0.667**	-0.046^{ns}
FGP	0.457**	0.296	0.104	0.426**	0.068	0.235	**1**	0.659**	0.005	1.000**	0.580**	-0.237	-0.084	0.523**
UGP	0.149	0.112	-0.181	0.218	-0.212	0.007	0.283	**1**	1.000**	0.600**	0.373*	-0.27	0.352*	0.615**
FTP	0.177	0.13	-0.131	0.106	-0.155	-0.185	0.222	0.151	**1**	-0.042	0.378*	-0.434**	0.633**	0.702**
TGP	0.427**	0.278	0.092	0.387*	0.063	0.153	0.951**	0.334*	0.288	**1**	0.531**	-0.151	-0.04	0.501**
BY	0.648**	0.565**	0.337*	0.539**	0.292	0.32	0.466**	0.251	0.252	0.418*	**1**	0.035	-0.356*	0.730**
TGW	-0.209	-0.031	0.464**	0.084	0.482**	0.368*	-0.122	-0.187	-0.034	-0.095	-0.013	**1**	-0.456**	-0.298^{ns}
HI	-0.058	-0.057	-0.566**	-0.281	-0.559**	-0.520**	-0.003	0.077	0.095	0.001	-0.332*	-0.231	**1**	0.381*
GY	0.532**	0.471**	-0.091^{ns}	0.278^{ns}	-0.125^{ns}	-0.082^{ns}	0.417^{ns}	0.246^{ns}	0.314*	0.382*	0.654**	-0.184^{ns}	0.430**	**1**

"**" significant at 1% and "*" significant at 5% ; respectively. By=Biomass Yield; DH= Days to Heading; CL=Culm Length; DM=Days to Maturity; FGP =Filled grains per Panicle; FLL=Flag Leaf Length; FTP= Fertile Tillers per plant=Fertile Tillers Per Plant; GY= Grain Yield kg per ha^{-1} HI=Harvest Index; TGP= Total grains per panicle; PH== Plant Height; PL= Panicle Length; TGW=Thousand Grains Weight ;UGP=Unfilled Grains Per Panicle.

correlation with yield at phenotypic level. Similar findings were reported by Nandan et al. (2010) for days to heading and Karim et al. (2014) who observed positive association between harvest index and yield. Indris et al. (2013 and Kishore et al. (2015) reported positive correlation of filled grains per panicle with yield. Laza et al. (2004) reported similarly for total spikelets per panicle with yield. Corresponding findings was noticed by Naseem et al. (2014) for days to maturity and total spikelets per panicle. Similarly, Fentie et al. (2014) confirmed positive correlation of biomass yield with grain yield. On the other hand, yield had non-significant but positive phenotypic correlation with unfilled grains per panicle (r_p=0.246), filled grains per panicle (r_p=0.417) and panicle length (r_p=0.278) which suggests that selection for these traits would not improve yield.

Phenotypic correlation between the traits

Correlations between yield components and other quantitative traits help in understanding the association between the characters. Days to heading exhibited positive and significant ($p<0.01$) phenotypic association with days to maturity (r_p=0.747**), panicle length (r_p=0.356*), filled grains per panicle (r_p=0.457**), biomass yield (r_p=0.648**) and total grains per panicle (r_p=0.427**). Days to maturity showed significant correlation at ($p<0.01$) with biomass yield (r_p=0.565**) while non-significant for the rest of traits.

Plant height showed positive and significant correlation with culm length (r_p=0.995**), flag leaf length (r_p=0.687**), panicle length (r_p=0.403*), above ground biomass yield (r_p=0.337*) and thousand grains weight (r_p=0.464**) and negative and significant correlation with harvest index (r_p=-0.566**). The finding is in conformity with Ghosal et al. (2010) and Kishore et al. (2015) for panicle length. Moreover, panicle length showed significant and positive association with culm length (r_p=0.333*), flag leaf length (r_p=0.539**), filled grains per panicle (r_p=0.426**), total grains per panicle (r_p=0.387*) and biomass yield (r_p=0.539**) but non-significant association with unfilled grain per panicle (rp=0.218), fertile tillers per plant (r_p=0.106), thousand grains weight (r_p=0.084) and harvest index (r_p=-0.281).

Culm length had significant and positive association with the traits such as flag leaf length (r_p=0.656**) and 1000-grain weight (r_p=0.482**) whereas it had negatively associated with harvest index (r_p=-0.559**). Flag leaf length manifested positive and significant association with 1000-grains weight (r_p=0.368*) and had negative association with harvest index (r_p=-0.520**). Number of filled grain per panicle showed a positive strong to moderate correlation with number of total grain per panicle (r_p=0.951**) and biomass yield (r_p=0.466**), respectively. However, contrary to the observation of Karim et al. (2014) who reported highly significant negative correlation between 1000-grains weight and number of filled grain per panicle. According to Adams and Grafius (1971), the negative correlations arise primarily from competition for a common possibility, such as nutrient supply. If one component gets advantage over the other, a negative correlation may arise. The genetic reasons for this type of negative association may be linkage or pleiotropy. Total grains per panicle revealed positive correlation with biomass yield (r_p=0.418*) and non-significant with thousand grains weight (r_p=-0.095) and harvest index (r_p=0.001), respectively. Biomass yield per plot had significant and negative association with harvest index (r_p=-0.332*).

Genotypic correlation coefficient

Some of traits genotypic correlation coefficients were higher than their corresponding phenotypic correlation coefficient values (Table 1) which indicates a fair strong inherent relationship between the traits due to suppressing effect of the environment, which may have modified the phenotypic expression of these traits by reducing phenotypic coefficient values at the period of characters' development. Similar findings were reported by Zahid et al. (2006) and Prasad et al. (2001). The yield component traits revealed various trends of association between themselves. For instance, days to heading (0.930**) followed by biomass yield (r_g=0.731**), filled grains per panicle (r_g=0.614**), total grains per panicle (r_g=0.588**), panicle length (r_g=0.509**) and unfilled grains per panicle (r_g=0.396*) showed significant and positive correlation ($p<0.01$) with days to maturity. Moreover, days to maturity manifested significant and positive correlation ($p<0.01$) with panicle length (r_g=0.446**), filled grains per panicle (r_g=0.459**), total grains per panicle (r_g=0.431**) and biomass yield (r_g=0.756**).

Plant height had significant and positive genotypic correlation with traits such as panicle length (r_g=0.450**), culm length (rg=0.997**), flag leaf length (r_g=0.783**) and biomass yield (r_g=0.337*); however, it had negative and significant association with unfilled grains per panicle (r_g=-0.402*) and harvest index (r_g=-0.702**). Likewise, Iftekharuddaula et al. (2001) reported highily significant and positive correlation of plant height with panicle length and negative correlation for harvest index. Similarly, Ghosal et al*.* *(*2010), Babu et al*.* *(*2012) and Kishore et al. (2015) reported positive correlation of plant height with panicle length. Panicle length was positively and significantly associated with culm length (r_g=0.369*), flag leaf length (r_g=0.511**), filled grain per panicle (r_g=0.503**), thousand grains weight (r_g=0.405*), unfilled grain per panicle (r_g=0.500**), total grain per panicle (r_g=0.524**) and biomass yield (r_g=0.729**). Harvest index had negative and significant association with panicle length (rg=-0.439**), culm length (-0.695**), flag leaf length (-0.667**), biomass yield (-0.356*) and thousand grains weight (-0.456**) while positive significant association with unfilled grains per panicle (0.352*). In contrast, Kishore et al. (2015) reported non-significant association with filled grain per panicle and thousand grains weight.

Filled grains per panicle had strong positive correlation with the total grains per panicle (1.000**) followed by unfilled grain per panicle (0.659**) and biomass yield (0.580**) but the rest traits indicated non-significant association. Unfilled grains per panicle showed positive correlation at genotypic level with total grains per panicle (0.600**), biomass yield (0.373*) and harvest index (0.352*). Fertile tillers per plant showed significant positive association with biomass yield (0.378*) and harvest index (0.633**) while it showed significant and negative correlation with thousand grains weight (-0.434**). Similarly, Rokonuzzaman et al. (2008) reported significant negative correlation for thousand grains weight. Total grains per panicle showed significant association with biomass yield (0.531**) but non-significant association with thousand grains weight and harvest index.

On the contrary, Iftekhlruddaula et al. (2001) observed significantly negative association with harvest index and thousand grains weight. Biomass yield manifested negative and significant association with harvest index (-0.356*). Culm length revealed positive and significant association with flag leaf length (0.756**) and thousand grains weight (0.685**) whereas it had negative and significant association with unfilled grain per panicle (-0.453**), fertile tillers per plant (-0.362*) and harvest index (-0.695**). Similarly, flag leaf length exhibited positive and significant correlation with thousand grains weight (0.497**) and biomass yield (0.411*). However, harvest index (-0.667**) and fertile tillers per plant (-0.347*) showed significant and negative correlation.

Path coefficient analysis

Grain yield is becoming a complex outcome of various traits which were considered to be the dependent trait. In the current study, thirteen traits were selected as casual variables to evaluate the contribution of these individual traits for yield (Table 2).

Direct effect of different traits on yield

A perusal result of genotypic path analysis revealed that biomass yield (1.052) followed by harvest index (0.722), total grains per panicle (0.643) and plant height (0.459) had highest direct effect on yield with significant and positive genotypic correlation across locations, which indicates the correlation that explains the true association with yield and direct selection through these traits will be effective. Hence, selection of genotypes with more total grains per panicle, harvest index, biomass yield and plant height is necessary to be emphasized during simultaneous selection to prove effectively increasing yield potential (Table 2). These traits have been identified as major direct contributors towards yield by Srek and Beper (2002) and Pratap et al. (2012) for biomass yield and harvest index for rice, respectively. Khare et al*.* *(*2014) reported similarly, the highest positive direct effect of the total grains per panicle on yield in earlier study. Sravan et al. (2012) reported a maximum direct effect of biological yield on yield followed by harvest index, and total grains per panicle in upland rice. Mulugeta (2015) reported biomass yield and plant height as the major contributors to yield and had direct effect on yield in

Table 2. Estimates of direct (bold diagonal and underlined) and indirect effect (off diagonal) at genotypic level of 13 traits on grain yield in 36 rice genotypes tested at Pawe and Fogera in 2015/16 cropping season.

Traits	DH	DM	PH	PL	CL	FLL	FGPP	UGPP	FTP	NTGPP	BY	TGW	HI	r_g
DH	**-0.02**	-0.063	-0.045	-0.032	0.08	0.03	-0.309	-0.102	0.037	0.378	0.769	0.015	-0.06	0.678
DM	-0.019	**-0.068**	-0.034	-0.028	0.067	0.029	-0.231	-0.04	0.000	0.277	0.796	0.005	0.049	0.803
PH	0.002	0.005	**0.459**	-0.028	-0.578	0.122	-0.038	0.104	-0.041	0.034	0.355	-0.033	-0.506	-0.145
PL	-0.01	-0.03	0.206	**-0.062**	-0.214	0.079	-0.253	-0.129	0.038	0.337	0.767	0.003	-0.317	0.415
CL	0.003	0.008	0.457	-0.023	**-0.58**	0.117	-0.022	0.117	-0.047	0.012	0.315	-0.034	-0.502	-0.178
FLL	-0.004	-0.013	0.359	-0.032	-0.438	**0.155**	-0.161	0.007	-0.045	0.199	0.432	-0.024	-0.482	-0.046
FGPP	-0.012	-0.031	0.035	-0.031	-0.025	0.05	**-0.503**	-0.169	0.001	0.648	0.611	0.012	-0.06	0.523
UGPP	-0.008	-0.01	-0.185	-0.031	0.263	-0.005	-0.331	**-0.257**	0.134	0.386	0.393	0.013	0.254	0.615
FTP	-0.006	0	-0.142	-0.018	0.21	-0.054	-0.003	-0.264	**0.131**	-0.027	0.397	0.021	0.457	0.702
NTGPP	-0.012	-0.029	0.024	-0.033	-0.011	0.048	-0.507	-0.154	-0.005	**0.643**	0.559	0.007	-0.029	0.501
BY	-0.015	-0.051	0.155	-0.045	-0.174	0.064	-0.292	-0.096	0.049	0.342	**1.052**	-0.002	-0.257	0.73
TGW	0.006	0.007	0.312	0.004	-0.397	0.077	0.119	0.069	-0.057	-0.097	0.037	**-0.049**	-0.329	-0.298
HI	0.002	-0.005	-0.322	0.027	0.403	-0.104	0.042	-0.091	0.083	-0.026	-0.374	0.022	**0.722**	0.381

Residual Effect=0.118; BY= Bimass Yield ;DH= Days to heading; CL= Culm Length; DM=Days to Maturity; FGPP =Filled Grains per panicle; FLL=Flag leaf length; FTP= Fertile tillers per plant; HI= Harvest Index; NTGPP= Number of total grains per panicle; PH= Plant height; Pl= Panicle length; TGW=Thousand Grains Weight; UGPP=Unfilled grains per panicle.

upland rice. Karim et al. (2014) and Kishore et al. (2015) reported that plant height had high direct positive effect on yield.

On the other hand, days to heading (-0.020), days to maturity (-0.068), panicle length (-0.062), culm length (-0.580), unfilled grains per panicle (-0.257), filled grains per panicle (-0.503) and thousand grains weight (-0.049) had negative direct loading on yield except on culm length, panicle length, and thousand grains weight but showed positive and significant genotypic correlation with yield. The negative direct effect indicates that the direct selection through these traits would not prove to be useful for the improvement of yield of rice. Similar results reported earlier by Mulugeta et al. (2012) for days to maturity and Kiani and Nematzadeh (2012) also noticed negative direct effect of panicle length on yield. On the contrary, Kiani and Nematzadeh (2012) reported the positive direct effect of filled grains per panicle on yield of rice.

Indirect effect of various traits on yield

The highest and positive indirect effect on yield shown by days to maturity through biomass yield (0.796), days to heading via biomass yield (0.769), panicle length through biomass yield (0.767), filled grains per panicle through total grains per panicle (0.648), filled grains per panicle by biomass yield (0.611), total grains per panicle by biomass yield (0.559), fertile tillers per panicle through harvest index (0.457) and culm length via plant height (0.457). Thus, indirect selection based on these traits should be considered simultaneously as indirect selection criteria for yield improvement. In contrast, Karim et al. (2014) reported negative indirect effect of panicle length on yield. The perusal of path analysis result indicated that plant height exhibited high negative indirect effect on yield through culm length (-0.578) and harvest index (-0.506), total grains per panicle through total grains per panicle (-0.507) and culm length via harvest index (-0.502). The indirect effect of days to heading through culm length (0.080), flag leaf length (0.030), fertile tillers per plant (0.037) total grains per panicle (0.378), biomass yield (0.769) and thousand grains weight (0.015) counter balanced the negative direct effect days to heading on yield (-0.020) and reduced the correlation coefficient to +0.678.

Correspondingly, the indirect effect of days to maturity through culm length (0.067), flag leaf length (0.029), fertile tillers per plant (0.0001) total grains per panicle (0.277), biomass yield per plot (0.796), thousand grains weight (0.005) and harvest index (0.049) counter balanced the negative direct effect of days to maturity on yield (-0.068) and reduced the correlation coefficients to +0.803. Moreover, the indirect effect of panicle length through plant height (0.206), flag leaf length (0.079), fertile tillers per plant (0.038), total grains per panicle (0.337), biomass yield (0.767) and thousand grains weight (0.003) counter balanced the negative direct effect of panicle length on grain yield (-0.062) and reduced the correlation coefficient +0.415. The negative direct effect of culm length on yield per hectare (-0.580) was counter balanced mainly by its positive indirect effects through plant height (0.457) and reduced its genotypic correlation to -0.178. Similarly, the indirect effect of filled grains per panicle mainly counter balanced through total grains per panicle (0.648) and biomass yield (0.611) reduced its genotypic correlation to +0.523.

The residual effect (0.118) showed that the traits which are included in the genotypic path analysis explained 88.2% of the total variation on yield that was contributed by thirteen traits studied. The residual 11.8% showed that there are some more traits that were not included in the present study but could contribute to yield. Most likely, biomass yield, harvest index, total grains per panicle and plant height has the highest direct effect on yield with significant and positive genotypic association. This indicates that the correlation revealed the true association and direct selection through these traits will be effective.

Conclusion

Yield exhibited positive and highly significant (P <0.01) genotypic correlation with traits like days to heading, days to maturity, filled grains per panicle, fertile tillers per panicle, harvest index, total grain per panicle and biomass yield, respectively. This indicates the importance of these traits for yield improvement in rice. Thus, the indirect selection for higher yield based on these characters would be reliable.

Path coefficient analysis revealed that biomass yield, harvest index and number of total grains per panicle had the highest direct effect on grain yield with significant and positive genotypic association, which indicates that the correlation explains the true association with grain yield and direct selection through those traits will be effective. Thus, selection of genotypes with more harvest index, biomass yield, plant height and total grains per panicle are important to develop high yielder varieties and an emphasis be given for these traits in future breeding efforts.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Growth, yield component and yield response of durum wheat (*Triticum turgidum* L. var. Durum) to blended NPS fertilizer supplemented with N rates at Arsi Negelle, Central Ethiopia

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Proper type and amount of fertilizer application is the major factor that affects yield and yield components of durum wheat. Hence, field experiment was carried out on farmer's field to determine the effect of blended NPS fertilizer (19% Nitrogen, 38% P_2O_5 and 7% Sulfur) in combination with nitrogen on growth, yield components, and yield of durum wheat. Factorial combinations of three blended NPS levels (100, 150, and 200 kg ha^{-1}) each supplemented with five levels of nitrogen (0, 23, 46, 69 and 92 kg ha^{-1}) and control were laid out in a randomized complete block design with three replications. The analysis of variance (ANOVA) indicates that the interaction effect of blended NPS and supplemented N significantly ($p < 0.05$) influenced number of total tillers and total productive tillers per m^2 where, highest total tillers (343.3) and productive tillers (306.7) per m^2 were recorded at the combination of 150 kg NPS ha^{-1} and 92 kg N ha^{-1}.However, those left parameters were not significantly influenced by the interaction of the two factors. The analysis of variance showed that the main effect of blended NPS was significantly ($p < 0.05$) influenced only grain yield and plant height where maximum grain yields (5274 kg ha^{-1}) and plant height (79.59 cm) were obtained at the highest application of 200 NPS kg ha^{-1}. The analysis of variance also showed that the main effect of supplemented N rate highly significantly ($p < 0.01$) influenced days to physiological maturity, grain filling period, thousand kernels weight, grain yield and harvest index but significantly ($p < 0.05$) influenced plant height and biomass yield. The highest days to physiological maturity (103 days), grain filling period (46.22 days), thousand kernels weight (50.49 g), plant height (79.49 cm), grain yields (5738 kg ha^{-1}), biomass yields (11728 kg ha^{-1}) and harvest index (48.91%) were recorded at the highest N rate (92 kg N ha^{-1}). The economic analysis revealed that for a treatment to be considered as worthwhile to farmers, application of 100 kg NPS ha^{-1} with 69 kg N ha^{-1} were profitable and recommended for farmers in Arsi Nagelle District.

Key words: Blended NPS fertilizer, durum wheat, supplemented N, yield components, yield.

INTRODUCTION

Wheat (*Triticum* species) is the most important staple food crop for more than one-third of the world population and contributes more calories and proteins to the world diet than any other cereal crops (Shewry, 2009). Global wheat production in 2014 was estimated at 729 million tons from 220 million ha area harvested with average yield of 3315.2 kg ha^{-1} (FAOSTAT, 2014).

In Ethiopia, wheat is mainly grown in the highlands, which lie between 6 and 16° N latitude and 35 and 42° E longitude, at altitudes ranging from 1500 to 2800 m above sea level and with mean minimum temperatures of 6 to 11°C (MoA, 2012). There are two types of wheat grown in Ethiopia and both of them are produced under rainfed conditions: durum (pasta and macaroni) wheat, accounting for 40% of production, and bread wheat, accounting for the remaining 60% (Bergh et al., 2012). Durum wheat (*Triticum turgidum* L. var Durum) is traditionally grown by smallholder farmers on the heavy black clay soils (Vertisols) of the high lands at altitude ranging between 1800 and 2800 m above sea level and rainfall distribution varying from 600 to more than 1200 mm per annum (January to December) in Ethiopia (Hailu, 1991).

Lack of soil fertility database and absence of area and crop specific fertilizer recommendation was taken as a key obstacle in realizing the first growth and transformation plan (GTP) of doubling agricultural production by the end of the five-year plan period (IFDC, 2015). In order to tackle this problem, the Ministry of Agriculture was conducting soil and plant nutrient survey to determine the key soil nutrient limitations along with importation of different blended fertilizers and micro-nutrients from abroad and test these against Urea (50 kg ha^{-1}) and di-ammonium phosphate (DAP, 100 kg ha^{-1}) for their impact on crop yield in different areas and crops. The results from both of these initiatives showed deficiency of 3 to 6 nutrients N, P, S, Zn, Mo and B. in most parts of the country and crops responded to the application of additional nutrient. Moreover, the plant analysis data from the same sites indicated that wheat plants were deficient in N, P, Zn and K (Hailu et al., 2015).

Due to this, Ethiopia is moving from blanket recommendations for fertilizer application rates to recommendations that are customized based on soil type and crop. This is a move towards diversification and away from DAP and Urea, which have long been the only type of fertilizer imported for grain crops.

The farmers in most parts of the country in general and in the study area in particular have limited information on the impact of different types and rates of fertilizers except blanket recommendation of nitrogen 41 kg N ha^{-1} (23 kg N/urea +18 kg N/DAP) and phosphorus (46 kg P_2O_5 ha^{-1}), that is, 50 kg Urea and 100 kg DAP per ha^{-1}. However, according to the soil fertility map covering over 150 districts, most of the Ethiopian soils lack about seven nutrients (N, P, K, S, Cu, Zn and B) (EthioSIS, 2013). Moreover, Assefa et al. (2015a) reported that grain yield and yield components of wheat (100%) fully responded to applied nitrogen, 72.3% showed response to sulfur, 78% showed response to applied phosphorus on eighteen fields studied in central high lands of Ethiopia and strongly indicated sulfur deficiency along with its importance to include in balanced fertilizer formula.

Apart from blanket recommendation of nitrogen and phosphorus, the effect of other fertilizers on yield components and yield of durum and bread wheat are unknown in Ethiopia, even though new blended fertilizers such as NPS (19% N, 38% P_2O_5 and 7% S) are currently being used by the farmers with blanket recommendation of 100 kg NPS ha^{-1} in Ethiopia. However, the rate of this fertilizer was not determined by researchers particularly for the study area and durum wheat production. In addition to this, the amount of N in the blended NPS is small as compared to the requirement of durum wheat. Thus, there is a need to supplement with nitrogenous fertilizer in the form of urea. Therefore, this study was undertaken with the following objectives:

(i) to assess the effect of rates of blended NPS and supplemental N fertilizers on growth, yield components and yield of durum wheat.
(ii) to determine economically appropriate rates of blended NPS and supplemental N fertilizers for durum wheat production.

MATERIALS AND METHODS

Description of the experimental site

The experiment was conducted during mid-July to October in 2016 cropping season on a farmer's field in Mako Oda Peasant Association, in Arsi Negelle District, West Arsi Zone of Oromia Regional State in Central Ethiopia. Mako Oda Peasant Association is situated at a distance of about 210 km from Addis Ababa in the South direction, and around 5 km from the Arsi Negelle Town. Geographic location of the district is 7° 17' N to 7° 66' N latitude and 38° 43' E to 38° 81' E longitudes (Google Earth, 2012). The elevation is 500 to 2000 masl; the area is characterized by erratic type of bimodal rainfall pattern; and the soil type of Arsi Negelle is mainly Vertisols and Alfisols with pH 7.5 (OoARD, 2009).

According to National Meteorological Services Agency (NMSA), Arsi Negelle had mean annual minimum and maximum temperatures of 8.14 and 27.89°C, respectively, while rainfall varied between 20 - 180 mm per month during cropping season (Figure 1). In general, the average monthly maximum and minimum temperatures and rainfall distribution are suitable for wheat production.

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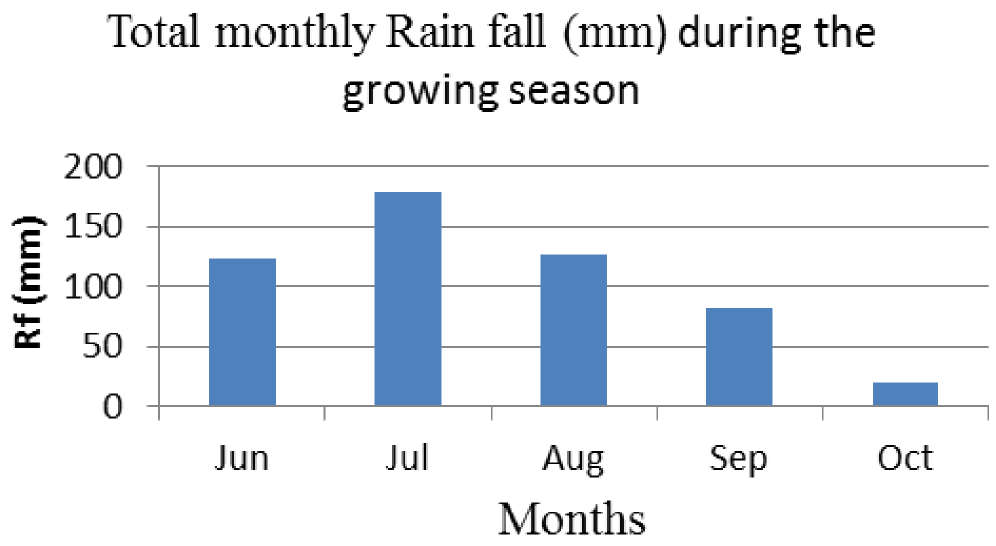

Figure 1. Total monthly rainfall (mm) during the growing season.

Experimental materials

Durum wheat variety Ude (CD 95294-2Y) and blended fertilizer in the form of NPS (19% N, 38% P_2O_5 and 7% S) were used, whereas urea (46% N) was used as a source of nitrogen.

Soil sampling and analysis

Before sowing, soil samples were taken randomly to a depth of 0 - 30 cm in a zigzag pattern to make one composite soil sample of the experimental field. The collected composite soil sample was air-dried, ground, and sieved using 2 mm sieve except for organic matter which was 0.02 mm sieve and was analyzed using standard laboratory procedures at Batu Soil Research Center.

Organic carbon was determined by Walkley and Black oxidation method (Walkley and Black, 1934). Total nitrogen was analyzed by Micro-Kjeldhal digestion method with sulfuric acid (Jackson, 1962). The total number of exchangeable cations a soil can hold, cation exchange capacity was determined after saturating the soil with 1 N ammonium acetate (NH_4OAc) and displacing it with 1 N NaOAc (Chapman, 1965). Available phosphorus was determined by the Olsen's method using a spectrophotometer (Olsen et al., 1954). Soil pH was measured in water at soil to water ratio of 1:2.5 (Van Reeuwijk, 1992). Soil texture was analyzed by Bouyoucous hydrometer method (Bouyoucous, 1951). Available Sulfur was determined using turbid metric method (Chesnin and Yien, 1951).

Treatments and experimental design

The treatments consisted of factorial combinations of three levels of NPS (100, 150 and 200 kg ha^{-1}) each supplemented with five levels of nitrogen (0, 23, 46, 69 and 92 kg ha^{-1}) and control that give a total of sixteen treatments. The experiment was laid out in randomized complete block design (RCBD) with three replications. The details of the treatments are shown in Table 1. The gross plot size was 3 m × 2 m (6 m^2) accommodating 10 rows each spaced 20 cm. Spacing of 1.0 m and 0.5 m was maintained in between adjacent blocks and plots, respectively. The outermost one row from each side of a plot and 25 cm from each end of the rows were considered as border, thus the net plot size was 2.5 m × 1.6 m (4 m^2).

Management of the experiment

The experimental field was prepared following the conventional tillage practice which includes four times plowing before sowing of the crop. As per the specification of the design, a field layout was prepared; the land was leveled and made suitable for crop establishment. Sowing was done on 6 July 2016 using seed rate of 125 kg ha^{-1}. Full dose of NPS as per the treatment and one-third of N alone was applied at sowing time. The remaining two-third of N alone was top dressed at the mid-tillering crop stage.

Data collection and measurement

Crop phenology and growth parameters

Days to heading: This was recorded as the number of days from the date of sowing till spikes in 50% of the plants emerged from each plot by visual observation.

Days to physiological maturity: This was determined as the number of days from sowing to the date when 90% of the peduncle turned to yellow straw color. It was recorded when no green color remained on glumes and peduncles from each plot by visual observation.

Grain filling period: It was determined as the number of days to maturity minus the number of days to heading.

Plant height (cm): This was measured from the soil surface to the tip of a spike (awns excluded) from 10 randomly tagged plants from the net plot area at physiological maturity.

Yield components and yield

Number of total tillers: These were counted from two rows of 0.5

Table 1. Days to 90% physiological maturity, grain filling period, and plant height as influenced by main effects of blended NPS and supplemented N rates.

Treatment	DPM	GFP	PH (cm)
NPS rate (kg ha^{-1})			
100	101.07^{a}	44.07^{a}	77.53^{b}
150	101.47^{a}	44.47^{a}	77.29^{b}
200	101.07^{a}	44.73^{a}	79.59^{a}
LSD (0.05)	NS	NS	1.63
N supplemented (kg ha^{-1})			
0	99.7^{a}	42.89^{c}	76.58^{a}
23	100.3^{ab}	43.56^{bc}	77.19^{ab}
46	100.9^{b}	44.11^{b}	78.27^{abc}
69	102.1^{c}	45.33^{a}	79.18^{bc}
92	103^{d}	46.22^{a}	79.49^{c}
LSD (0.05)	0.8	0.9	2.1
CV (%)	0.9	2.1	2.8
Treated mean	101.20^{A}	44.42^{A}	78.63^{A}
Control mean	95.67^{B}	41.0^{B}	71.83^{B}
LSD (0.5)	4.1	2.7	3.4
CV (%)	1.2	1.8	1.3

Means within a column followed by the same letter are not significantly different at 5% level of significance according to Fisher protected LSD test; DPM = Days to physiological maturity; GFP = Grain filling period; PH = Plant height, CV = coefficient of variation; LSD = Least significant difference.

m length selected randomly per net plot at physiological maturity and converted to m^2.

Number of productive tillers: These were counted at physiological maturity from two randomly selected rows of 0.5 m in length from the net plot as above and converted to m^2.

Number of kernels per spike: This was recorded as an average of 10 randomly taken spikes from the net plot area.

Thousand kernel weight: This was determined based on the weight of 1000 kernels sampled from the grain yield of each net plot by counting using electronic seed counter and weighed with electronic sensitive balance. Then the weight was adjusted to 12.5% moisture content.

Aboveground dry biomass yield: This was determined from plants harvested from the net plot area after sun drying to a constant weight and expressed in kg ha^{-1}.

Grain yield: This was taken by harvesting and threshing the grain yield from net plot area. The yield was adjusted to 12.5% moisture content and expressed as yield in kg ha^{-1}.

Harvest index (HI): This was calculated as ratio of grain yield per plot to total above ground dry biomass yield per plot expressed as percent.

Statistical analysis

The data was subjected to analysis of variance (ANOVA) as per the experimental design using GenStat (15th edition) software (GenStat, 2012). The Least Significance Difference (LSD) at 5% level of probability was used to determine differences between treatment means.

Partial budget analysis

The economic analysis was carried out by using the methodology described in CIMMYT (1988) in which prevailing market prices for inputs at planting and for outputs at harvesting were used. All costs and benefits were calculated on ha basis in Birr. The concepts used in the partial budget analysis were the mean grain yield of each treatment, the gross benefit (GB) ha^{-1} (the mean yield for each treatment) and the field price of fertilizers (the costs of NPS and Urea and the application costs). Cost of straw yield was not included in the calculation in the benefit since the farmers in the area do not use it. Marginal rate of return, which refers to net income obtained by incurring a unit cost of fertilizer, was calculated by dividing the net increase in yield of durum wheat due to the application of each fertilizers rate. The net benefit (NB) was calculated as the difference between the gross benefit and the total cost that vary (TCV) using the formula

$$NB = (GY \times P) - TCV$$

where GY × P = Gross Field Benefit (GFB), GY = Adjusted Grain yield kg per hectare and P = field price kg of the crop.

Actual yield was adjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers could expect from the same treatment.

The dominance analysis procedure as described in CIMMYT (1988) was used to select potentially profitable treatments from the range that was tested. The discarded and selected treatments using this technique were referred to as dominated and undominated treatments, respectively. For each pair of ranked treatments, % marginal rate of return (MRR) was calculated using the formula:

$$\text{MRR (\%)} = \frac{\text{Change in NB (NBb}-\text{NBa)}}{\text{Change in TCV (TCVb}-\text{TCVa)}} \times 100$$

where NB_a = NB with the immediate lower TCV, NB_b = NB with the next higher TCV, TCV_a = the immediate lower TCV and TCV_b = the next highest TCV.

The % MRR between any pair of un-dominated treatments was the return per unit of investment in fertilizer. To obtain an estimate of these returns, the % MRR was calculated as changes in NB (raised benefit) divided by changes in cost (raised cost). Thus, a MRR of 100% implied a return of one Birr on every Birr spent on the given variable input.

The fertilizer cost was calculated for the cost of each fertilizer of NPS (Birr 14.54 kg^{-1}) and N/UREA (Birr 10.60 kg^{-1}) during sowing time. The cost of NPS and Urea application is Birr 1454 and 1060 ha^{-1}, respectively; and the average open price of durum wheat at Arsi Negelle market was Birr 7 kg^{-1} in October 2017 during harvesting time. The application cost of NPS and two times urea application was 200 birr ha^{-1}.

RESULTS AND DISCUSSION

Soil physico-chemical properties of the experimental site

Selected physico-chemical properties of the soil were analyzed at Ziway Soil Research Center, for composite surface soil (0-30 cm depth) samples collected before sowing of the crop. On the basis of particle size distribution, the soil contained 37.9% sand, 45.9% silt and 16.2% clay (Table 1). According to the soil textural class determination triangle, the soil of the experimental site is loam which is suitable for durum wheat production (Miyan et al., 2011).

The available P content of the soil was 6.8 ppm which was medium according to the rating of Landon (1991). This indicates the need for external application of phosphorus fertilizer sources for good crop growth and yield (FAO, 2008). The soil reaction of the experimental site (pH = 5.6) is moderately acidic, according to the rating of Tekalign (1991). According to Roy et al. (2006), the suitable pH range for wheat crop is between 5.5 and 7.0. Thus, the pH of the experimental soil is within the range for productive soils.

Percent organic matter content of the soil is 3.1 and medium according to Tekalign (1991) which indicates that the soil has medium potential to supply mineralizable nitrogen to the plants during growth. Electrical conductivity of the experimental soil is 0.17 mmhos/cm and low according to rating of Horneck et al. (2011), which indicates the suitability of the soil for crop production.

Cation exchange capacity (CEC) is an important parameter of soil, because it gives an indication of the type of clay mineral present in the soil and its capacity to retain nutrients against leaching. According to Landon (1991), top soils having CEC greater than 40 cmol (+) kg^{-1} are rated as very high, 25 - 40 cmol (+) kg^{-1} as high, 15 - 25, 5 - 15 and < 5 cmol (+) kg^{-1} of soil are classified as medium, low and very low, respectively, in CEC. According to this classification, the soil of the experimental site had high CEC (28.36 meq/100 g soils).

Tekalign (1991) has classified soil total N content of < 0.05% as very low, 0.05 - 0.12% as poor, 0.12 - 0.25% as moderate and > 0.25% as high. According to this classification, the soil samples were found to have moderate level of total N (0.17%) (Table 2), indicating that the nutrient is a limiting factor for optimum crop growth. The available sulfur content of the soil was 6.5 ppm which is medium according to the rating of Horneck et al. (2011).

Crop phenology and growth parameters

Days to 50% heading

Analysis of variance revealed that days to 50% heading was not significantly affected by main effect of blended NPS fertilizer rates and supplemented N rates. Moreover, blended NPS and N supplemented did not significantly interact to influence days to 50% heading. However there was significant ($P < 0.05$) difference between treated mean and control mean where the treated mean reached days to heading at late (56.78 days) than the control treatment 54.67 days. This result showed that days to heading ranged between 56.33 to 57.67 days. Delay of treated mean for days to heading might be due to adequate NPS in the soil which kept vegetative growth active and consequently resulted in delayed days to 50% heading.

Days to 90% physiological maturity

The main effects of supplemented N rates were highly significantly ($P < 0.01$) on days to 90% physiological maturity. However, the main effect of blended NPS fertilizer rates and interaction effect of the two factors did not significantly influence days to 90% physiological maturity, but significant ($P < 0.05$) variation was also found between treated mean and control mean for days to 90% physiological maturity.

Significant variations were found among the different levels of supplemented N for 90% physiological maturity period. Increasing the amount of supplemented N increased highly significantly days to 90% physiological maturity. The highest number of days required for 90% physiological maturity (103 days) was recorded in the

Table 2. Total number of tillers/m^2 as influenced by interaction effect of blended NPS and supplemented N rates.

NPS (kg ha^{-1})	N Supplemented (kg ha^{-1})				
	0	23	46	69	92
100	158.3^{g}	191.7^{efg}	206.7^{defg}	278.3^{b}	238.3^{bcde}
150	165.0^{fg}	210.0^{cdefg}	196.7^{efg}	268.3^{bc}	343.3^{a}
200	213.3^{cdefg}	223.3^{bcdef}	228.3^{bcde}	261.7^{bcd}	235.0^{bcde}
Treated mean			213.9^{A}		
Control mean			111.7^{B}		

	NPS × N	Treated vs. control
LSD (0.05)	61.30	53.24
CV (%)	16.1	9.3

Means within columns and rows followed by the same letter are not significantly different at 5% level of significance according to Fisher protected LSD test; CV = coefficient of variation; LSD = Least significant difference.

highest rate of N supplemented (92 kg N ha^{-1}) while no N fertilizer supplementation showed the shortest growth period for days to 90% physiological maturity (99 days). Increasing the rate of N supplemented from 0 to 23 and 23 to 46 kg ha^{-1} increased days to physiological maturity by 0.60%, which were statistical at par. Likewise, the treated mean delayed physiological maturities by 5.78% as compared to control mean (Table 1).

The prolonged time period required by the plants to reach maturity at higher rate of nitrogen may be attributed to the increase in leaf area duration, increased vegetative growth and increased light use efficiency. In line with this result, Shazma et al. (2016) reported that, increasing the rates of nitrogen resulted in increased number of days taken to maturity of wheat crop where the maximum days to maturity (170) was taken by the plots treated with 150 kg N ha^{-1} and less number of days to maturity (160) was observed in control plots.

Generally, the number of days to maturity recorded as mean of all treated plots was significantly higher than that of unfertilized plot. The result is also in agreement with Yohannes (2014) who reported that increasing of N application significantly prolonged days to physiological maturity of bread wheat at Haramaya and Meta where maximum number of days to physiological maturity (110) and (105.7) days were observed under plots received 138 kg N ha^{-1} in three splits while the lowest (105.7) and (102.7) days were recorded from 46 kg N ha^{-1} with two split applications at Haramaya and Meta respectively.

Grain filling period

The main effects of N supplemented rates was highly significantly ($P<0.01$) on grain filling period (Table 3). However, the main effect of blended NPS fertilizer rates and interaction effect of the two factors did not significantly influence grain filling period. There was significant difference ($P<0.05$) between control mean and treated mean for days to grain filling period.

Grain filling period, which is the number of days from heading to maturity, was increased with increasing rate of supplemented N. Thus, increasing the rates of N supplemented from nil to the highest 92 kg N ha^{-1} increased days for grain filling period by about 7.76%. Similarly, the treated mean delayed grain filling period by 8.34% as compared to control mean (Table 1) Increased grain filling period as the nitrogen rates increased might be due to sufficient soil nitrogen present in the soil that makes plants to take up nitrogen from the time the roots begin to function until all uptake of nutrients ceases with maturity which could have extended green canopy duration by delaying whole plant senescence and extend the grain filling period.

This result is in line with Sofanyas (2016) who reported, increased grain filling period with increasing of N rates and recorded the maximum (33.44) and (45.11) days for bread wheat at Suluh site in Hawzien and Atsela and Ayba in Emba Alaje, respectively, in Tigrayi Region.

Plant height

Analysis of variance showed that the main effects of blended NPS and supplemented N rates was significant ($P<0.05$) on plant height while the interaction effect of the two factors was not significant. However significant ($P<0.05$) variation was also found between treated mean and control mean for plant height.

Increasing the amount of both NPS and N rates significantly increased plant height. The maximum application rate of blended NPS (200 kg ha^{-1}) r esulted in

Table 3. Number of productive tillers/m^2 as affected by interaction of blended NPS fertilizer and supplemented N rates.

NPS (kg ha^{-1})	**N Supplemented (kg ha^{-1})**				
	0	**23**	**46**	**69**	**92**
100	138.3^{f}	170.0^{def}	180.0^{cdef}	251.7^{ab}	213.3^{bcd}
150	141.7^{ef}	175.0^{def}	180.0^{cdef}	233.3^{bc}	306.7^{a}
200	195.0^{bcdef}	210.0^{bcd}	180.0^{cdef}	235.0^{bc}	201.7^{bcd}
Treated mean			190.2^{A}		
Control mean			91.7^{B}		

	NPS ×N	**Treated vs. control**
LSD (0.05)	58.25	33.53
CV (%)	17.2	6.8

Means within columns and rows followed by the same letter are not significantly different at 5% level of significance according to Fisher protected LSD test; CV = coefficient of variation; LSD = Least significant difference.

the highest plant height (79.59 cm). Similarly, the highest plant height (79.49 cm) was recorded in the highest N rate (92 kg ha^{-1}) supplemented while no N fertilizer supplementation showed the shortest plant height (76.58 cm) (Table 1). Similarly, treated mean increased plant heights by 9.47% as compared to control mean (Table 1).

The increased plant height in response to increasing rate of nitrogen application was probably due to the vital role of N fertilizer in promoting the vegetative growth and resulted in significant increase in plant height. In agreement with this result, Abdo et al. (2012) found maximum plant height of 89.4 cm for durum's wheat at maximum application of 69 kg N ha^{-1}.

Moreover, this result is in line with results of Melesse (2017) who reported that application of N and P fertilizer rates highly significantly ($P<0.01$) increased plant height of bread wheat and recorded the highest height of 94.18 and 90.56 cm at applications of 69 kg N ha^{-1} and 30 kg P ha^{-1}, respectively. The result is also parallel with Dagne (2016) who reported that application of Togo blended fertilizer NPKSBZn (26:11:11:3.5:0.15:0.6) kg ha $^{-1}$ with micro nutrient Cu+Zn (5+5 L ha^{-1}) increased plant height of maize by 66.81% over control plot and 6.11% over recommended NP fertilizers at Kejo farmers field.

Yield components and yield

Total number of tillers

Main effect of supplemented N was highly significant ($p<0.01$) on total numbers of tillers per m^2 while the effect of blended NPS rate was not significant. Moreover, the interaction effect of NPS and supplemented N rates was significant ($P<0.05$) on total numbers of tillers per m^2. Similarly, there was significant ($P<0.05$) difference between control mean and treated mean on total number of tillers/m^2. The highest number of tillers (343.3 per m^2) was obtained at 150 kg NPS ha^{-1} and 92 kg N ha^{-1} supplemented while the lowest total number of tillers (158.3 per m^2) was recorded at 100 kg NPS ha^{-1} with nil N supplemented (Table 2). Total number of tillers per meter square variably responded to blended NPS and N supplemented. The treated mean increased total number of tillers/m^2 by 91.5% over control mean.

The highest number of tillers at the highest rates of NPS and N might be due to the increase in number and size of growing cells, ultimately resulting in increased number of tillers. The improvement in total number of tillers with NPS application might be due to the role of P found in NPS in emerging radicle and seminal roots during seedling establishment in wheat (Cook and Veseth, 1991). This result is in agreement with that of Shay et al. (2011) where they obtained the highest tillers (348.00 per m^2) in treatment that received the highest nitrogen (120 kg N ha^{-1}) than control (235.30 per m^2). Similarly, Mahammad (2015) reported significant increase in number of tillers of bread wheat as application of NPK enhanced from 0-0-0 to 175-75-50 kg ha $^{-1}$, respectively, and recorded the maximum number of tillers (389 per m^2) at application of 140-75-50 kg NPK ha^{-1}. Generally, number of tillers per plant recorded as the mean of overall treated plots was significantly higher (213.9 per m^2) than the unfertilized plot/control (111.7 per m^2) (Table 2).

Number of productive tillers

Main effect of supplemented N was highly significant ($p <0.01$) on total numbers of productive tillers/m^2 while blended NPS rate was not significant. Moreover, the interaction effect of blended NPS and supplemented N was significant ($P <0.05$) on numbers of productive tillers/m^2. Also, there was significant ($P < 0.05$) difference between control mean and treated mean on total number of productive tillers/m^2.

The highest number of productive tillers (306.7/m^2) was obtained at 150 kg NPS ha^{-1} and 92 kg N ha^{-1} supplemented while the lowest number of productive tillers (138.3/m^2) was recorded at 100 kg NPS ha^{-1} with nil supplemented N (Table 3). Similarly, number of productive tillers was higher by 107.4% over without fertilizer application. Total number of productive tillers per meter square variably responds to blended NPS and N supplemented as enhanced from the lower rates to the highest rates. The increase in the number of productive tillers produced in response to the increased application rates of N fertilizer may be due to the roles played by N in enhancing tiller production by the plant. Thus, stimulation of tillering with optimal application of N might be due to its positive effect on cytokinin synthesis.

This result is concurrent with Chonde (2015) who reported maximum fertile tillers/m^2 (290.5) with the application of 150 kg N ha^{-1} and 100 kg P_2O_5 ha^{-1}. Likewise, Mengistu (2015) recorded highest number of productive (416 tillers/m^2) in treatment that received 175 kg N ha^{-1} than control (317.1 tillers per m^2). Also, Assefa et al. (2015) reported that combined application of 138/115 kg/ha N P_20_5 resulted in maximum number of effective tillers (319.7 per m^2) and increased number of effective tillers by 19.2% as compared to blanket recommendation (46 N/46 P_20_5) kg/ha.

Number of kernels per spike

Analysis of variance showed that number of kernels per spike was not significantly affected by main effects of blended NPS fertilizer and supplemented N rates. Interaction of blended NPS fertilizer and supplemented N rates did not significantly influence number of kernels per spike. In addition there was no significant difference between treated mean and control mean on number of kernels per spike.

The possible reason for non-response of number of kernels per spike to applied NPS and N rates might be due to the low level of difference in nutrient amount among treatments which translocated from vegetative part to kernels during grain filling stage. This result indicated the number of kernels per spike ranges in between 37.67 (100 NPS, 0 N) to 47.60 (100 NPS, 92 N) kg ha $^{-1}$.

Thousand kernels weight

Main effect of supplemented N showed highly significantly ($P < 0.01$) effect while main effects and interaction blended NPS did not show significant effect on thousand kernels weight. However, there was significant ($P<0.05$) difference between control mean and treated mean on thousand kernels weight. Abdo et al. (2012) found thousand kernels weight ranges of 42.5 to 49.5 g for durum wheat varieties.

The maximum thousand kernels weight (50.49 g) was recorded in response to nitrogen supplemented at rate of 92 kg ha^{-1}. While the lowest (47.39 g) was recorded from plot treated with zero N kg ha^{-1} supplementation and there was an increment of 6.54% in thousand kernels weight among the highest 92 kg ha^{-1} and zero N supplementation (Table 4). Also, treated mean was higher by 6.56% over control mean (Table 4) which could be due to improvement of seed quality and size due to nitrogen.

In line with this result, Rahman et al. (2011) reported maximum 1000 kernels weight (49.4 g and 46.6 g) for wheat in two consecutive years by application of 120 kg N ha^{-1}. Moreover, Mandic et al. (2015) and Ali et al. (2016) reported enhanced thousand kernels weight with increased nitrogen level from nil to the highest. Tilahun et al. (2017) also reported the highest thousand kernels weight (59.99 g) at the highest N rate (92 kg ha^{-1}) for durum wheat.

Biomass yield

Biomass yield was highly significantly ($p < 0.01$) affected by the main effects of N supplemented but the main effect of blended NPS fertilizer rates as well as its interaction with N supplemented did not significantly influence biomass yield. Also, there was significant ($P<0.05$) difference between control mean and treated mean on biomass yield.

Biomass yield increased as the rate of N supplemented increased from zero to 92 kg N ha^{-1}. Maximum biomass yield (11728 kg ha^{-1}) was obtained at maximum (92 kg N ha^{-1}) supplemented N and lowest biomass yield (10150 kg ha^{-1}) was obtained at nil N supplemented. Also, the biomass from the treated mean was higher by 27.37% over control mean (Table 4).

The increase in biological yield with supplemented N rates might be due to sufficient nitrogen in the soil which favors vegetative wheat plant growth such as leaf area, leaf area index (LAI) which increases light interception and so more total dry matter production occurred at various growth stages. The result was in conformity with report of Assefa et al. (2015b) who reported that biomass yield of bread wheat increased with increasing applied NP fertilizer in a consistent manner and reported highest biomass yield (11.89 t/ha) at the highest rate of (138/115 N/P_2O_5 kg ha^{-1}).

Grain yield

Main effect of blended NPS fertilizer and supplemented N

Table 4. Thousand kernels weight, biomass, yield and harvest index of durum wheat variety as influenced by main effect of Blended NPS fertilizer and N supplemented rates.

Treatment	**TKW (g)**	**BM (kg ha^{-1})**	**GY(kg ha^{-1})**	**HI (%)**
NPS rate (kg ha^{-1})				
100	48.72^{a}	10687^{a}	4830^{b}	45.14^{a}
150	49.22^{a}	11070^{a}	5054^{ab}	45.66^{a}
200	49.14^{a}	11107^{a}	5274^{a}	47.45^{a}
LSD (0.05)	NS	NS	228.6	NS
N supplemented (kg ha^{-1})				
0	47.39^{c}	10150^{c}	4294^{c}	42.42^{c}
23	48.19^{c}	10750^{bc}	4758^{b}	44.27^{bc}
46	49.69^{ab}	10806^{bc}	5012^{b}	46.64^{ab}
69	49.37^{b}	11339^{ab}	5461^{a}	48.17^{a}
92	50.49^{a}	11728^{a}	5738^{a}	48.91^{a}
LSD (0.05)	0.9	739.5	295.2	2.91
CV (%)	1.9	7.0	6.1	6.6
Treated mean	49.02A	10954A	5095.4A	46.12A
Control mean	46.0B	8600B	3322.5B	38.55B
LSD (0.05)	1.5	1797.9	1185.98	7.3
CV (%)	1.5	5.3	8.0	5.0

Means within a column followed by the same letter are not significantly different at 5% level of significance according to Fisher protected LSD test; TKW = Thousand kernels weight; BM= Biomass yield; GY = Grain yield; HI% = Harvest index in percent.

rates had significant ($p < 0.05$) and highly significant ($p<0.01$) influence, respectively, on grain yield (Table 4). However, the interaction of blended NPS fertilizer and supplemented N rates did not significantly influence grain yield. On the other hand there was significant ($P<0.05$) difference between control mean and treated mean on grain yield.

Increasing the rates of blended NPS fertilizer from 100 to 200 kg ha^{-1} and supplemented N from 0 to 92 kg ha^{-1}, the grain yield showed consistent increase. The highest grain yield (5274 kg ha^{-1}) and (5738 kg ha^{-1}) was obtained in response to application of 200 kg ha^{-1} blended NPS and 92 kg ha^{-1} N supplemented, respectively. While the lowest grain yield (4830 kg ha^{-1}) and (4294 kg ha^{-1}) was obtained in response to application of 100 kg ha^{-1} blended NPS and zero kg ha^{-1} supplemented N, respectively. Similarly, treated mean increased grain yield by 53.36% over control mean (Table 4). The highest (200 kg ha^{-1}) and the lowest 100 kg ha^{-1} blended NPS fertilizer rates were statistically at par with 150 kg NPS ha^{-1}. Apart from nil rates of N supplemented, the preceding rate was not significantly different from the succeeding rates. Generally the highest (200 kg ha^{-1}) of blended NPS and the highest 92 kg ha^{-1} of supplemented N enhanced grain yield by 9.2 and 33.6% as compared to 100 kg NPS ha^{-1} and nil N kg ha^{-1} supplemented, respectively.

The highest grain yield at the highest NPS and N rates might have resulted from improved root growth and increased uptake of nutrients and better growth favored due to synergetic effect of the three nutrients which enhanced yield components and yield. Nitrogen affects the vegetative as well as yields whereas phosphorus plays a fundamental role in metabolism and energy producing reaction and can withstand the adverse environmental effects, thus resulting in enhanced grain yield.

This result is concurrent with Shah et al. (2011) who reported maximum grain yield (4145.14 kg ha^{-1}) from plots treated with 120 kg N ha^{-1}, while minimum grain yield (2479.17) was recorded from control plots. The result is also in agreement with Bereket et al. (2014) who reported that grain yield of bread wheat significantly increased due to the main effect of nitrogen and phosphorus fertilization as well as obtained highest grain yields (4443 kg ha^{-1}) and (3988 kg ha^{-1}) at applications of 138 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1}, respectively. Malle et al. (2017 reported that application of 100 kg N/ha in combination with 13.6 kg S ha^{-1} resulted in highest grain yield of 9.26 tons ha^{-1} while the lowest 3.47 tons ha^{-1} was recorded from control plot for winter wheat.

Harvest index

Analysis of variance showed that harvest index (%) was

Table 5. Partial budget and marginal analysis for blended NPS and supplemented N rate of durum wheat

NPS (kg ha^{-1})	N (kg ha^{-1})	Adjusted grain yield down wards by 10% (kg ha^{-1})	Gross Benefit (Birr ha^{-1})	Total variable cost (Birr ha^{-1})	Net return (Birr ha^{-1})	MRR (%)
Control	Control	2991	20935	0	20935	0
100	0	3750	26252	1654	24798	D
100	23	3986	27903	2184	25919	D
100	46	4360	30517	2714	28003	591
100	69	4975	34826	3244	31782	1818
100	92	4663	32640	3774	29066	D
150	0	3884	27185	2018	25367	788
150	23	4133	28930	2548	26582	499
150	46	4591	32136	3078	29258	327
150	69	4721	33044	3608	29636	D
150	92	5413	37888	4138	33950	D
200	0	3960	27720	3108	24812	D
200	23	4728	33094	3638	29656	930
200	46	4581	32067	4168	28099	D
200	69	5048	35337	4698	30839	150
200	92	5416	37913	5228	32885	D

NPS cost = 14.54 Birr kg^{-1}, UREA cost = 10.60 Birr kg^{-1} of N, NPS, durum wheat grain per ha = 7 Birr kg^{-1}, NPS and Urea application cost = 200 Birr ha^{-1}, MRR (%) = Marginal rate of return, D= Dominated treatment, Control = unfertilized.

significantly ($p < 0.05$) affected by main effect of supplemented N rates. However, the main effects of blended NPS fertilizer and the interaction of both factors did not significantly influence harvest index where there was significant ($P < 0.05$) difference between control mean and treated mean on harvest index.

Harvest index was increased with increasing application of N supplemented. The maximum harvest index (48.91%) was recorded with N supplemented at rate of 92 kg ha^{-1} which was statistically at par with preceding N supplementation of 69 and 46 kg ha^{-1} while the lowest harvest index (42.42%) was recorded with nil supplemented N. Similarly, in the treated mean, the harvest index was higher by 19.64% over control mean (Table 4) which was statistically at par with N supplementation of 23 kg ha^{-1}. The increment in harvest index at highest rate of supplemented N might be attributed to greater photo assimilate production and its ultimate partitioning into grains compared to partitioning into straw, that is, proportionally higher grain yield than vegetative biomass yield.

In agreement with this result, Liu and Shi (2013) reported increased harvested index of winter wheat as N application increased from nil to 225 kg ha^{-1} and obtained the highest harvest index of 0.45 at the highest N rate of 225 kg ha^{-1}. Esayas (2015) reported that durum wheat variety variably responded to blended fertilizers (N, P, S, Zn and B) and obtained the highest harvest index (33%) for variety Yerer and 42% for varieties Mangudo and Mukiye.

Partial budget analysis

To identify treatments with the optimum return to the farmer's investment, marginal analysis was performed on non-dominated treatments. For a treatment to be considered as worthwhile to farmers, between 50 and 100% marginal rate of return (MRR) was the minimum acceptable rate of return (CIMMYT, 1988). As indicated in Table 5, the partial budget and dominance analysis showed that the highest net benefit 31,782 Birr ha^{-1} was obtained in the treatment that was treated with 100 kg ha^{-1} blended NPS and 69 kg ha^{-1} N supplemented while the lowest net benefit 2,0935 Birr ha^{-1} was obtained in the control treatment. The highest marginal rate of return 1.818% was obtained from the plot treated with 100.69 kg ha^{-1} blended NPS and N supplemented respectively. According to this criterion, a farmer's investment of one Birr in 100.69 kg ha^{-1} NPS and supplementation N on durum wheat variety (Ude) recoups the one Birr and gives an additional 18.18 Birr.

Conclusion

Low volumes and poor quality of the national durum wheat production compels Ethiopia pasta industries to import the required raw material. Proper amount of fertilizer application in type and amount is the major constraints limiting durum wheat yield and grain quality. Due to this, Ethiopia is moving towards diversification and away from blanket recommendation of DAP and Urea, which have long been the only types of fertilizer imported for grain crops to blended fertilizer NPS which contains nutrients N: P_2O_5: S: 19:38:7. However, no studies have been undertaken in the study area on the effect of blended NPS on productivity and quality of durum wheat. Hence, field experiment was carried out to determine the effect of blended NPS in combination with supplemental nitrogen on growth, yield and grain quality of durum wheat in Arsi Negelle district, on a farmer's field during 2016 cropping season.

The treatments consisted of factorial combination of three levels of NPS (100, 150 and 200 kg ha^{-1}) and five levels of supplemental nitrogen (0, 23, 46, 69 and 92 kg ha^{-1}) and control (no fertilizer). The experiment was laid out as a randomized complete block design (RCBD) and replicated three times per treatment. The main effect of blended NPS fertilizer was not significant on crop phenology, growth parameters and yield components parameters, but it significantly ($P < 0.05$) influenced plant height and grain yield. Increasing the rate of blended NPS fertilizer from 100 to 200 kg ha^{-1} increased grain yield and the highest grain yield (5274 kg ha^{-1}) was obtained at the highest (200 kg ha^{-1}) of blended NPS fertilizer.

The main effect of supplemented N fertilizer was significant on crop phenology and growth parameters except days to heading, yield components and yield parameters excluding number of kernels per spike, days to heading, number of kernels per spike, with all tested parameters highly significantly ($p<0.01$) influenced by supplemented N fertilizer. The 92 kg N ha^{-1} gave the highest thousand kernels weight (50.49 g), highest days for 90% physiological maturity (103 days), grain filling period (46.22 days), plant height (79.49 cm), biomass (11728 kg ha^{-1}), grain yield (5738 kg ha^{-1}), and harvest index (48.91%). The result also indicated that number of total tillers per m^2 and productive tillers per m^2 was significantly influenced by interaction of blended NPS fertilizer and supplemented N where the highest total tillers (343.3 per m^2) and productive tillers (306.7 per m^2) was obtained at combination of 150 kg NPS ha^{-1} and 92 kg ha^{-1} N supplemented. Moreover, the result indicated that apart from number of kernels per spike, the fertilizer treated means were significantly higher over control (no fertilizer application).

The economic analysis revealed that for a treatment to be considered worthwhile to farmers (100% marginal rate of return), application of 100 kg NPS ha^{-1} with 69 kg N ha^{-1} supplementation are profitable and recommended for farmers in Arsi Negelle district.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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