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Full Length Research

Determinant of optimum plant density, nitrogen and phosphorus fertilization for different wheat genotypes

D. D. Majaivana[1]*, L. I Magwende[1] and Haile F. Olonga[2]

[1]Tigray Agricultural Research Institute (TARI), Alamata Agricultural Research Center, P. O. Box, 056, Alamata, Ethiopia.
[2]Ethiopian Agricultural Research Institute (EIAR), Kulmussa Agricultural Research Center, Assela, Ethiopia.

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Optimum seeding rate and nitrogen (N) and phosphorus (P) fertilization are the most important production factors for higher grain yield. Indiscriminate use of seeding rates and N and P fertilization does not only increase production costs but usually decrease wheat grain yield. Study on the interaction effect of planting density and N and P-fertilizer levels on bread wheat varieties was conducted in 2014 cropping season on vertisols of Ofla and Emba-Alaje districts of southern Tigray, Ethiopia with the objective of determining the optimum plant density and optimum N and P fertilization for different Wheat genotypes. The experiment contained split-split plot design on which three recently released bread Wheat varieties (Mekelle 3, Mekelle 4 and Danda'a) were assigned as a main plot, Four level of N/P_20_5 combination (46/46, 92/69, 115/92 and 138/115 kg N/P_20_5 ha^{-1}) arranged in a sub plot and four levels of planting density (150, 300, 400 and 500 plant/m^2) assigned as sub-sub plot factor and replicated three times. The analysis of variance indicate that variety, fertilizer, planting density, variety x fertilizer, variety x planting density, fertilizer x planting density, and variety x fertilizer x planting density interaction, have significant (P<0.05) effect on grain yield of bread Wheat varieties. Nitrogen and phosphorus fertilizers and variety showed significance (P<0.05) effect on biomass yield, seeds per spike, effective tiller number and plant height. Grain yield, plant height, effective tiller number/m^2 and biomass yield of bread wheat variety increase linearly with planting density and N/P205 fertilizer rate. More grain (6.93 and 5.21 t/ha) for Emba-Alaje and Ofla, respectively was recorded from the interaction effects of 138/115 kg of N/P_20_5 ha^{-1} with 300 plant/m^2 planting density for variety Mekelle-3. However, 115/92 kg of N/P_20_5 ha^{-1} with planting density of 500 plants/m^2 reached higher economical return (MRR=3166.12).

Key words: Variety, planting density, economic analysis, fertilizer.

INTRODUCTION

The agricultural sector in Ethiopia accounts for more than 40% of national GDP, 90% of exports, and provides basic needs and income to more than 90% of the poor (UNDP, 2002). In Ethiopia, Wheat is the major cereal crop grown in the highlands with altitudes of 1500 to 3200 m.a s.l. However, the most suitable regions fall between 1900 and 2700 m above sea level (white et al., 2001) with 6 and 16°N latitude, 35 and 42°E longitude.

Ethiopia is the second largest producer of wheat in sub-Saharan Africa following South Africa and about 1.61 million hectare of land is cultivated for both bread and durum wheat production under rain fed conditions. About

*Corresponding author. E-mail: dd.maja92@gmail.com.

60% of the wheat area is covered by bread wheat and 40% by durum wheat. In area of production, Wheat ranks 4th after teff, maize, and sorghum and 3rd in total grain production after Maize and Teff and 2nd in yield to Maize. It is cultivated by 4.746 million farmers and accounts for more than 16.3% of the total cereal production (CSA, 2014). However, the mean national and regional yield is 2.45 and 1.82 t/ha, respectively, which is 3-4 t/ha far below the experimental yields of over 6 t/ha.

Conversely, most Ethiopian soils are deficient in nutrients, especially nitrogen and phosphorus, and as such fertilizer application has significantly increased yields of crops (Asnakew et al., 1991; Tekalign et al., 2001). Low availability of nitrogen and phosphorus (Asnakew et at., 1991, Tekalign et at., 1988; Amsal et at., 1997a) has been reported to be a major constraint to Wheat production in Ethiopia.

Nitrogen and phosphorus are the most deficient than any other essential plant elements in Ethiopian soils (Abebe, 1965). An inadequate supply of N and P fertilizer greatly reduces yields and profit. Too much N can result in logging, decreased yields and reduced profits. Determining the optimum N and P fertilizer rates is the key to maximize economic yields. Plant density is also major factor determining the ability of the crop to capture resources and generate yield. It can be developed by using a suitable seeding rate. Maximum genetic potential of high yielding Wheat varieties cannot be harvested without ensuring proper seeding rate. As the plant density increases, the competition for resources especially for nitrogen also increases, which badly affect the ultimate grain yield (Nazir et al., 2000).

None of the recommended bread Wheat varieties were evaluated for seed rate and NP fertilizer response in the study area. The introduction of high yielding bread Wheat genotype accompanied with improved production technology packages like optimum NP fertilizations with optimum planting density could markedly increase productivity per a given hectare. Therefore, the present study was initiated with the objective of determining the optimum plant density and optimum nitrogen and Phosphorus fertilization for different Wheat genotypes.

MATERIALS AND METHODS

Description of experimental area

An experiment was conducted in 2014 main cropping season at Ofla and Emba-Alaje districts of south Tigray, Ethiopia. Ofla is located on the geographic coordinates of $13^0$89'85''-$13^0$97'50'' north latitude and $51^0$94'00''-$56^0$21'36'' east longitude and an altitude between 1800-2440 m above sea level. Mean annual rain fall is 1000 mm with daily temperature ranged 10-22°C, while Emba-Alaje is located on the geographic coordinates of $14^0$22'71''- $14^0$39'17''north latitude and $53^0$05'15''-$56^0$01'42'' East longitude and altitude of 2350 m.a.s.l. The mean annual rain fall for Emba Alaje is 630 mm. The 15 year annual rain fall distribution for the districts is presented in Figure 1. The dominant soil type is clay for the both the study sites.

Experimental design, treatments and experimental procedure

The experimental design was split-split plot design replicated three times. The treatments are as follows:

A). Main Plot factor: three of bread Wheat varieties

1) Variety 1= Mekelle 3
2) Variety 2= Mekelle 4
3) Variety 3= Danda'a

B). Sub-plot factor: four levels of fertilizers

1) 46/46 kg N/ P_2O_5 ha^{-1}
2) 92/69 kg N/ P_2O_5 ha^{-1}
3)115/92 kg N/ P_2O_5 ha^{-1}
4) 138/115 kg N/ P_2O_5 ha^{-1}

C). Sub-sub-plot factor: four **planting densities**

1) 150 plants/m^2
2) 300 plants/m^2
3) 400 plants/m^2
4)500 plants/m^2

The seed rate calculations from given planting density were done as:

$$Seed\ rate\ (kg/ha) = \frac{Taeget\ \ plant\ (\#/m^2)\ *1000\ seed\ weight}{Likely\ \ established\ \ (\%)}$$

Data analysis

The Analysis of Variance (ANOVA) for the studied variables was computed using the GLM procedure of SAS software version 9.2 (SAS institute, 2000) following the standard procedures of ANOVA for RCB design (Montgomery, 1991). The differences among Variety, planting density and fertilizer were considered significant if the P-values were ≤ 0.05. Least Significance Test (LSD) was used to compare among treatments at 5% probability level.

Partial budget analysis

Grain yield data for the variety, fertilizer and planting density effects were subjected to economic analysis, using the CIMMYT (1988) partial budget methodology to evaluate the economic profitability of fertilizer and seed rate options for determination of the economic optimum rate. Wheat yields were adjusted downwards by 10% to

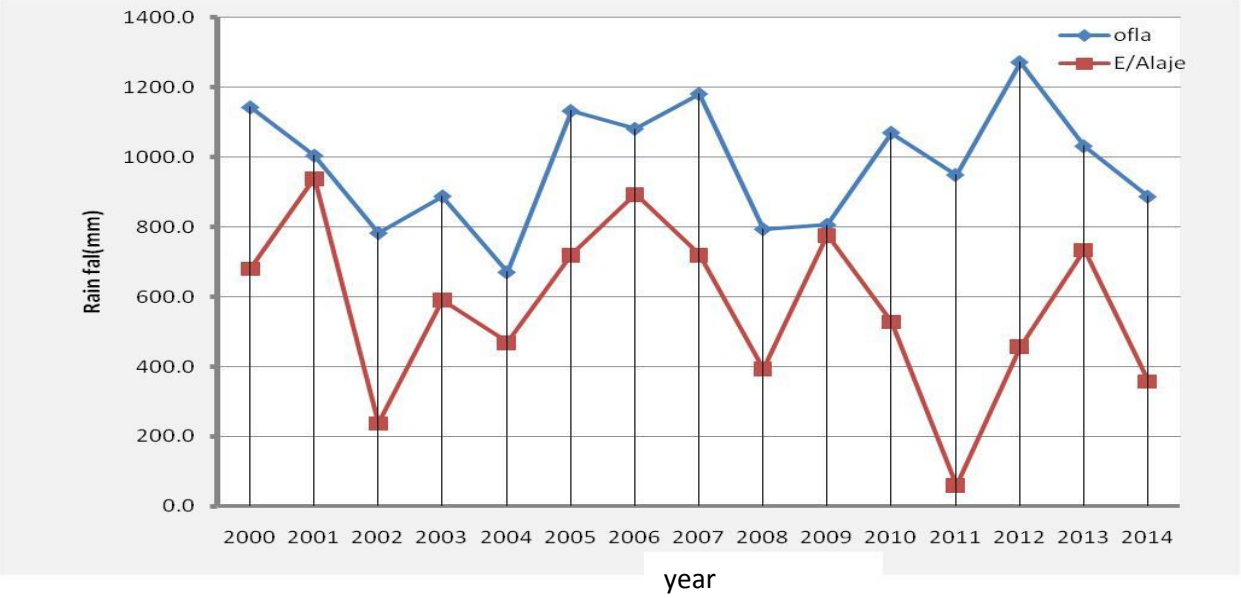

Figure 1. Fifteen years rain fall pattern of Ofla and Alaje areas.

more closely approximate yields. Wheat variety, NP fertilizer rates and seed rates were analyzed separately by calculating Gross Benefit (GB), Total Costs that Vary (TCV), Net Benefit (NB), and the Marginal Rate of Return (MRR) for each treatment (that is, relative to the next lowest cost or non-dominated treatment for the NP and seed rate analysis). Dominance analysis was used to screen treatments which have higher variable cost and lower net return and dominated treatment removed from further consideration.

RESULTS AND DISCUSSION

Response of bead wheat variety to different planting density and NP fertilizer level

The analysis of variance (ANOVA) revealed that main effects of treatments were significant ($P<0.05$) for plant height, effective tillers /m^2, biomass yield and seeds per spike across locations except planting density for plant height and biomass yield (Table 2). Moreover, NP fertilizer x Planting density were significance ($P<0.05$) for responsive variable of effective tiller/m^2 and biomass yield.

The treatment mean comparison indicates that most of the response variable were enhanced linearly with the increased levels of NP-fertilizer. Hence, highest values for all parameters were recorded from 138 /115 kg ha^{-1} N/P_2O_5 fertilizer rate application (Table 3). The mean comparison showed planting population per m^2 was increased with the levels of seed rate. Besides, planting density is negatively related to spike length and seeds per spike. Hence, highest value of spike length and seeds per spike was recorded from the lower planting density (seed rate). The reason may be due to increased intra-row competition that can slow down growth of plants at higher seed rates.

The mean comparison showed that all the yield related response variables included in this study were linearly enhanced by NP fertilizer rates. Thus, highest values of plant height, effective tillers per m^2, spike length, seeds per spike and biomass yield were obtained from the maximum fertilizer (138/115 N/P_2O_5 kg ha^{-1}). Varieties showed difference in potential in response to the yield components. Regarding to plant height and seeds per spike variety, Danda'a showed better performance. Mekelle 3 scores the highest plant population per m^2 and biomass yield, as compared to the other varieties. However, Mekelle 4 showed relatively better performance in response to spike length (Table 3). Generally, Emba-Alaje district was relatively suitable environment as compared to Ofla in response to all yield related components considered in the study.

The second level interactions, NP fertilizer rate x planting density was significant on number of effective tillers per m^2 (Table 2) and highest number of effective tillers per m^2 was recorded from the combination of 92/69 N/P_2O_5 kg ha^{-1} × 500 pl/m2 followed by 115/92 kg ha^{-1} × 500 pl/m^2. Besides, the lowest was obtained from the combination of 46/46 N/P_2O_5 kg ha^{-1} and 150 planting density /m^2 (Table 4).

The second level interactions, location x variety and NP fertilizer rate x seed rate and third level interactions of Loca x Var x NP fertilizer rate were significant ($p<0.05$) on biomass yield (Table 2). The treatment mean comparison

Table 1. Seed rate used for each plant density for each of the varieties.

Plant density /m^2	Seed rate (kg/ha)		
	Mekelle 3	Mekelle 4	Danda'a
150	66	72.63	79
300	132	145.26	158
400	177	193	210
500	221	242	263

Table 2. Combined mean square values for the agronomic traits of bread Wheat genotypes.

Source of variation	d.f.	Plant height (cm)	Tiller number(/m^2)	Seed Per spike S	Bio mass yield M(t ha^{-1})	Grain yield (t $ha^{-1)}$
Rep stratum	2	299.3	204298	9.0717	5.481	0.3485
Location(Loc)	1	6371***	3122917***	1.2246ns	956.778***	179.227***
Variety(Var)	2	2431.2***	91278***	41.1661***	12.017*	5.4718***
NP fertilizer rate	3	767.4*	35404***	2.0917**	67.74***	5.8289***
Planting density(PD)	3	157.3ns	33427***	2.1855**	7.337ns	3.5655***
Loc x Var	2	46.1ns	724ns	0.5556ns	15.69**	4.3071***
Loc x NP fertilizer rate	3	199.8ns	20093**	0.2971ns	9.279ns	2.1302***
Var x PD	6	258.8ns	461ns	0.2581ns	5.063ns	0.9056**
Loc x PD	3	223.3ns	584ns	0.1906ns	1.306ns	0.6418ns
Var x NP fertilizer rate	6	393.4ns	508ns	0.2484ns	3.585ns	1.0563**
NP fertilizer rate x PD	9	264.7ns	46373***	0.7182ns	26.884***	3.5120***
Loc x Var x PD	6	249.9ns	3021ns	0.2304ns	12.89**	1.0644**
Loc x Var x NP fertilizer rate	6	335.5ns	2296ns	0.1255ns	0.269**ns**	3.1582***
Loc x NP fertilizer rate x PD	9	408.4ns	2519ns	0.7081ns	2.481ns	0.5684*
Var x NP fertilizer rate x PD	18	201.7ns	2340ns	0.2234ns	3.497ns	0.5351*
Loc x Var x NP fertilizer rate x PD	18	234.2ns	1430ns	0.0732ns	4.273ns	1.0414***
Residual	190	246.2	4922	0.48	3.878	0.2931

***=significance at p=0.001, **=significance at p=0.01 and *=significance at p=0.05.

of biomass also showed that both varieties increase with the increasing applied NP-fertilizer in a consistent manner. Besides, Emba- Alaje was relatively higher response to NP fertilizer rate and variety on biomass yield compared to Ofla destricts. Higher biomass yield was obtained from Mekelle 3 variety with application of 138/115 $kgha^{-1}$ N/P_20_5 at Emba-Alaje and Mekelle 4 variety with application 92/69 $kgha^{-1}$ P_20_5 at Ofla (Table 5).

Effects of variety, planting density and NP fertilizer rates on grain yield of bread wheat varieties

Yield is an important criterion in evaluating the adoptability of crops to an environmental variation. Analysis of variance indicated that fertilizer rate, seeding density, variety, variety by fertilizer interaction, variety by seed rate interaction, fertilizer by seed rate interaction and variety x fertilizer x seed rate interaction significantly ($P<0.05$) (Table 1) affect the grain yield, suggesting the existence of sufficient variability among varieties tested in the area, thus, the use yield optimization of Wheat is possible by providing different varieties of Wheat, with optimum level of fertilization and seed rate application for producers in a given area.

The genotype Mekelle 3 shows better grain yield at the highest rate of nitrogen and phosphorus fertilization (138/115 kg ha^{-1} N/P205 with 177 kg ha^{-1} seed rate for meklle3 and 138/115 kg ha^{-1} N/P205 fertilization with 193 kg ha^{-1} seed rate for Mekelle 4), while genotype Danda'a gave maximum grain on 115/92 kg ha^{-1} N/P205 with seed rate of 260 kg ha^{-1}, this may probably be due to the highest response by these genotype to N and P and their efficiency use (Table 7). Hailu (1991) emphasized N and P fertilizer application for Wheat production in Ethiopia to increase the yield of Wheat. Asnakew et al. (1991) again emphasized the use of N and P in Wheat production in Ethiopia. In other study, higher seed rare at 125 kg ha^{-1} had significantly higher grain yield of 1150.3 and 1175.6

Table 3. Effect of main factor treatments on plant height, effective tillers, spike length, seeds per spike and biomass yield.

Planting density/m^2	Plant height(cm)	Effective tiller	Spike length(cm)	Seeds per spike	Biomass yield (t/ha)
150	94.43	276.8b	7.649a	38.39a	10.76
300	93.04	289.6b	7.416b	37.12ab	11.12
400	96.16	296.5b	7.323b	36b	11.21
500	96.04	327.5a	7.248b	35.65b	11.53
LSD	Ns	23.06	0.2278	2.062	ns
N/P_2O_5 (kg/ha) rate					
46/46	90.23b	268.2c	7.196c	34.67c	9.78c
92/69	95.68a	294.5b	7.37bc	36.71bc	11.17b
115/92	95.97a	308.2ab	7.47ab	36.95ab	11.78ab
138/115	97.8a	319.7a	7.6a	38.83a	11.89a
LSD	5.158	23.06	0.2278	2.062	0.647
Variety					
Mekelle 3	96.37a	333.2a	6.931c	34.23c	11.52a
Mekelle 4	89.32b	278.4b	8.155a	37.09b	11.13ab
Danda'a	99.06a	281.3b	7.141b	39.05a	10.82b
LSD	4.467	19.97	0.1973	1.786	0.561
Location					
Ofla	90.21	193.5	7.34	34.29	9.33
Emba-Alaje	99.62	401.8	7.47	39.3	12.98
LSD	3.647	16.31	0.1611	1.458	0.458
CV	16.5	23.6	9.4	17	17.7

Table 4. Interaction effect of seed rate and NP-fertilizer rate on number of effective tillers per m^2.

N/P_2O_5 (kg ha^1) rate	Planting density/m^2			
	150	300	400	500
46/46	210.4	246.2	282.0	334.0
92/69	222.8	295.0	302.9	357.3
115/92	319.8	308.1	249.6	355.2
138/115	354.4	309.1	351.5	263.7
	Fertilizer x Seed rate			
LSD		46.13		
CV (%)		23.6		

Table 5. Interaction effect of location, variety and seed rate on biomass yield of bread Wheat genotypes.

Location	Variety	N/P_2O_5 (kg ha^{-1}) Rate			
		46/46	92/69	115/92	138/115
Emba- Alaje	Mekelle 3	10.38	13.26	13.26	14.66
	Mekelle 4	12.29	12.84	14.13	13.81
	Danda'a	11.22	12.21	13.53	14.14
Ofla	Mekelle 3	9.71	10.3	10.46	10.15
	Mekelle 4	7.05	8.21	10.57	10.12
	Danda'a	8.02	10.22	8.72	8.45
		Loc x Var x NP			
	LSD		3.172		
	CV (%)		17.7		

Table 6. Effect of main factor treatments on grain yield.

Planting density/m^2	GY(t ha^{-1})
150	4.41
300	4.49
400	4.71
500	4.90
LSD	0.18
N/P_2O_5 (kg/ha) rate	
46/46	4.27
92/69	4.54
115/92	4.81
138/115	4.89
LSD	0.18
Variety	
Mekelle 3	4.90
Mekelle 4	4.48
Danda'a	4.5
LSD	0.15
Location	
Ofla	3.84
Emba-Alaje	5.2
LSD	0.13
CV	11.7

Table 7. Interaction effect of seed rate and N and P fertilizer on grain yield of bread Wheat variety.

Variety	Seed rate (kg/ha)	Ofla				Emba Alaje			
		N/P_2O_5 (kg/ha)				N/P_2O_5 (kg/ha)			
		46/46	92/69	115/92	138/115	46/46	92/69	115/92	138/115
Mekelle 3	66	3.52	3.17	5.11	4.38	3.48	4.97	4.77	6.37
	132	3.86	4.09	4.82	4.54	4.46	4.15	5.26	6.20
	177	4.75	4.30	3.90	5.21	5.67	5.62	4.88	6.93
	221	4.99	4.80	4.80	3.00	5.24	6.29	6.51	6.90
Mekelle 4	72	1.71	2.55	4.43	3.95	5.14	5.19	6.01	6.31
	145	2.90	3.23	3.94	3.40	5.22	5.40	5.72	4.40
	193	2.87	3.25	3.47	4.20	5.24	5.51	4.57	6.28
	242	3.24	3.88	4.85	3.82	5.73	5.91	5.53	5.56
Dandaa	79	4.00	3.83	3.79	3.00	4.26	4.38	5.09	6.37
	158	4.17	3.61	3.46	3.53	4.32	5.99	5.65	5.51
	210	3.93	4.20	3.46	3.97	5.10	4.89	5.09	5.82
	263	2.95	4.58	3.64	3.24	5.67	5.14	6.74	4.61
		Variety x NP rate planting Density							
		LSD	0.6165						
		CV (%)	11.7						

Table 8. Simple correlation coefficients (r) between average yield and yield traits of Wheat genotypes.

	GY	PH	ET	SL	SPS	BM
GY						
PH	0.263***					
ET	0.671***	0.234***				
SL	0.72*	0.624*	-0.199			
SPS	0.162**	0.537*	0.101	0.192*		
BM	0.788***	0.288***	0.659***	0.117*	0.159***	

PH= plant height, ET= effective tillers, SL=Seeds per spike, SPS= seeds per spike, BM= biomass, ***=significance at p=0.001, **=significance at p=0.01 and *=significance at p=0.05.

Table 9. Partial budget analysis for variety 1(Mekelle 3).

Fertilizer rate (kg/ha)	Seed rate (kg/ha)	GY (t/ha)	GY adjusted	GB (GY)	BY (t/ha	GB (BY)	Total GB	TVC	NB	MRR %
46/46	66	3.50	3.15	34650	7.6	3060.1	37710.1	3453.4	34256.7	
46/46	132	4.16	3.744	41184	9.5	3800.0	44984	4106.8	40877.2	1013.24
46/46	177	5.21	4.689	51579	11.7	4720.8	56299.8	4552.3	51747.5	2440.02
46/46	221	5.12	4.608	50688	11.4	4580.1	55268.1	4987.9	50280.2	
92/69	66	4.07	3.663	40293	9.9	3972.9	44265.9	5653.4	38612.5	
92/69	132	4.12	3.708	40788	11.5	4612.3	45400.3	6306.8	39093.5	73.62
92/69	177	4.96	4.464	49104	12.5	5030.5	54134.5	6752.3	47382.2	1860.54
92/69	221	5.55	4.995	54945	13.3	5332.1	60277.1	7187.9	53089.2	1310.15
115/92	66	4.94	4.446	48906	13.1	5275.8	54181.8	6853.4	47328.4	1722.21
115/92	132	5.04	4.536	49896	12.1	4857.6	54753.6	7506.8	47246.8	
115/92	177	4.39	3.951	43461	8.9	3594.9	47055.9	7952.3	39103.6	
115/92	221	5.65	5.085	55935	13.3	5348.1	61283.1	8387.9	52895.2	3166.12
138/115	66	5.37	4.833	53163	12.7	5123.0	58286	8453.4	49832.6	
138/115	132	5.37	4.833	53163	12.4	5002.3	58165.3	9106.8	49058.5	
138/115	177	6.07	5.463	60093	13.7	5525.1	65618.1	9552.3	56065.8	1572.91
138/115	221	4.95	4.455	49005	10.7	4302.6	53307.6	9987.9	43319.7	

Where GY=Grain yield, BY=Biomass Yield,GB= Gross Benefit,TVC=Total Variable Cost,NB=Net Benefit and MRR =Marginal Rate of return.

kg ha^{-1} compared to the lowest Seed rate of 75 kg ha^{-1} which had the lowest grain yield of 1018.7 and 1033.6 $kgha^{-1}$ (Njuguna et al., 2010). Hamid et al. (2002) and Khan et al. (2002) also concluded that maximum grain yield was obtained with the increase in seed rate while minimum grain yield was produced by low seed rate. Studies conducted by Amsal et al. (1997) to determine the effects of crop management factors in four priority Wheat production zones of' Ethiopia indicated an increase of 13-315% due to improved variety, 20-88 % due to the application of 60/26 N/P kg ha^{-1} fertilizer. Mekelle 3 Variety gives high grain yield than the other varieties evaluated in the area with determined fertilizer and seed rate. This is due to that the earliness of this variety which helps to escape the terminal drought in the late September (Figure 1) that affects the late maturing Danda'a variety. Grain yield is the most complex trait and it is influenced by genetic and environmental factors that determine productivity of the genotype. Therefore, understanding of interrelationships of grain yield and other traits are highly important for formulating selection criteria. The Pearson correlation coefficients among the characters are presented in Table 8. Grain yield had strong significant positive correlations with biomass yield (BM, r=0.79), (SL, r = 0.73) and number of tillers per plant (ET, r = 0.67). This indicated that the yield increase is attributed to increased spike length, biomass yield, and effective tiller numbers. These characters contributed positively towards total variation in yield, and should be considered when selecting for high grain yield.

Partial budget analysis

Marginal rate of return (MRR) analysis were done for the sixteen treatments combinations under varying costs and prices (Tables 9, 10 and 11) for each genotypes. In economic analysis, it is assumed that farmers require a

Table 10. Partial buget analysis variety 2 (Mekelle 4).

Fertilizer rate (kg/ha)	Seed rate (kg/ha)	GY (t/ha)	GY adjusted	GB (GY)	BY (t/ha	GB (BY)	Total GB	TVC	NB	MRR %
46/46	72	3.42	3.078	33858	9.2	3703	37561	3512.8	34048.2	
46/46	145	4.06	3.654	40194	10.2	4105.5	44299.5	4235.5	40064	832.41
46/46	193	4.05	3.645	40095	8.7	3501.75	43596.75	4710.7	38886.05	
46/46	242	4.49	4.041	44451	10.6	4266.5	48717.5	5195.8	43521.7	955.61
92/69	72	3.87	3.483	38313	9	3622.5	41935.5	5712.8	36222.7	
92/69	145	4.32	3.888	42768	10.9	4387.25	47155.25	6435.5	40719.75	622.26
92/69	193	4.38	3.942	43362	10.7	4306.75	47668.75	6910.7	40758.05	8.06
92/69	242	4.89	4.401	48411	11.4	4588.5	52999.5	7395.8	45603.7	998.89
115/92	72	5.22	4.698	51678	12.3	4950.75	56628.75	6912.8	49715.95	
115/92	145	4.83	4.347	47817	12.7	5111.75	52928.75	7635.5	45293.25	
115/92	193	4.02	3.618	39798	10.8	4347	44145	8110.7	36034.3	
115/92	242	5.19	4.671	51381	13.7	5514.25	56895.25	8595.8	48299.45	2528.38
138/115	72	5.13	4.617	50787	12.6	5071.5	55858.5	8512.8	47345.7	1149.09
138/115	145	3.9	3.51	38610	11.9	4789.75	43399.75	9235.5	34164.25	
138/115	193	5.24	4.716	51876	12.6	5071.5	56947.5	9710.7	47236.8	2750.96
138/115	242	4.69	4.221	46431	10.8	4347	50778	10195.8	40582.2	

Where GY=Grain yield, BY=Biomass Yield, GB= Gross Benefit, TVC=Total Variable Cost,NB=Net Benefit and MRR =Marginal Rate of Return.

Table 11. Economic analysis for variety 3 (Danda'a).

Fertilizer rate (kg/ha)	Seed rate (kg/ha)	GY(t/ha)	GY adjusted	GB (GY)	BY (t/ha	GB (BY)	Total GB	TVC	NB	MRR %
46/46	79	4.13	3.717	40887	8.7	3490.4	44377.4	3582.1	40795.3	
46/46	158	4.24	3.816	41976	9.3	3751.7	45727.7	4364.2	41363.5	72.65
46/46	210	4.52	4.068	44748	10.5	4234.3	48982.3	4879.0	44103.3	532.21
46/46	263	4.31	3.879	42669	9.9	3997.0	46666	5403.7	41262.3	
92/69	79	4.11	3.699	40689	11.0	4427.3	45116.3	5782.1	39334.2	
92/69	158	4.80	4.32	47520	10.0	4021.2	51541.2	6564.2	44977	721.49
92/69	210	4.55	4.095	45045	11.8	4724.9	49769.9	7079.0	42690.9	
92/69	263	4.86	4.374	48114	12.1	4869.6	52983.6	7603.7	45379.9	512.48
115/92	79	4.44	3.996	43956	11.4	4592.2	48548.2	6982.1	41566.1	613.55
115/92	158	4.55	4.095	45045	11.3	4547.9	49592.9	7764.2	41828.7	33.58
115/92	210	4.28	3.852	42372	10.0	4013.1	46385.1	8279.0	38106.1	
115/92	263	5.19	4.671	51381	11.8	4749.0	56130	8803.7	47326.3	1757.23
138/115	79	4.69	4.221	46431	11.6	4648.5	51079.5	8582.1	42497.4	2179.10
138/115	158	4.52	4.068	44748	11.7	4684.7	49432.7	9364.2	40068.5	
138/115	210	4.90	4.41	48510	12.6	5046.6	53556.6	9879.0	43677.6	701.07
138/115	263	3.92	3.528	38808	9.4	3796.0	42604	10403.7	32200.3	

Where GY=Grain yield, BY=Biomass Yield, GB= Gross Benefit, TVC=Total Variable Cost, NB=Net Benefit and MRR =Marginal Rate of Return.

minimal rate of return of 100%, representing an increase in net return of at least 1 Birr for every 1Birr invested, to be sufficiently motivated to adopt a new agricultural technology. In the interaction effect of N/P fertilizer level, seed rate and variety, higher net margins were shown at 150 plants/m^2 (177 kg ha^{-1} seed rate) and 138/115 kg ha^{-1} N/P205 with net benefit of 52895.2 Birr, this gave marginal rate of return of MRR=3166.1% per birr invested for variety, fertilizer and seeding rate. Applying high fertilizer rate without increasing seed rate or increasing seed rate without increasing fertilizer level had lowest net income realized, however, investing more than 138/115 $kgha^{-1}$ N/P205, seems non profitable. In ofla and Emba Alaje Wheat growing areas, Mekelle 3 variety produce

maximum economic return with studied seed rate and fertilizer level flowed by variety Mekelle 4 and Danda'a, respectively.

Conclusion

The results from the study suggest that application of 115/92 kg of N/P205 ha^{-1} with 221 kg ha^{-1} (500 plants/m^2) seed rate, 138/115 N/P205 kg ha^{-1} with 193 kg ha^{-1} (400 plants/m^2) seed rate and 138/115 N/P205 kg ha^{-1} with 79 kg ha^{-1} (150 plants/m^2) seed rate reached better economical return with maximum grain yield production for Mekelle 3, Mekelle 4 and Danda'a variety, respectively in the study areas.

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