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FARMERS' PARTICIPATORY EVALUATION OF WHEAT (*TRITICUM AESTIVUM L.*) YIELD IN RESPONSE TO NITROGEN AND PHOSPHOROUS FERTILIZERS APPLICATION AT KOKATE MARA CHARE, WOLAITA ZONE, SOUTH ETHIOPIA

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ABSTRACT

Wheat (Triticum aestivum L.) a principal traditional cereal crop in the highlands of Ethiopia and is produced exclusively under rain fed conditions at altitudes ranging from 1500 to 3000 m.a.s.l.. The field trial was conducted at farmer's field at Kokate Mara Chare Kebele, Sodo Zuria Woreda, Wolaita Zone of South Ethiopia in the main rainy season of 2014. Five levels of nitrogen (0, 46, 69, 92 and 115 kg ha^{-1}) and phosphorous (0, 10, 20, 30 and 40 kg ha^{-1}) were used to evaluate productivity of wheat in response to NP fertilizers and to identify the most suitable NP rates for production of wheat of wheat under participatory approach by using Farmers' Research Group (FRG). Wheat variety "Digalo" was used for the experiment in a factorial Randomized Complete Block Design (RCBD) with three replications. Application of nitrogen (N) fertilizer had very highly significantly influenced total biomass, grain and straw yields of wheat but the effect of P and its interaction with N were not significant on these parameters. The highest grain yield (30.35 dt ha^{-1}) was obtained from the application of 92 kg N ha^{-1}. The economic analysis conducted by taking the grain yield into account revealed that the highest net benefit was obtained from the application of 92 kg N ha^{-1} and 0 kg P ha^{-1}. Farmers' crop stand evaluation result also indicated that most of the participating farmers preferred application of 92 kg N ha^{-1} and 0 kg P ha^{-1}. Therefore, application of 92 kg N ha^{-1} is recommended for production of wheat at Kokate Mara Chare. Based on the current finding, application of P for production of wheat at Kokate Mara Chare is not required. However, periodic checking of P status of soil and crop response to it is important.

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INTRODUCTION

Wheat is a principal traditional cereal crop in the highlands of Ethiopia and is produced exclusively under rain fed conditions at altitudes ranging from 1500 to 3000 m.a.s.l. (Hailu, 1991). Currently, wheat is one of the major cereals dominating food habits and dietary practices and is known to be a major source of energy and protein for the highland population of the country (Abera, 1991). The consumption of wheat products is thought to make up about 20% of the energy supplied in the worldwide total human diet (Dukes *et al*., 1995). In several countries, it provides more human nourishment than any other food sources (Stoskopf, 1985).

The early immigrant brought wheat to Ethiopia some 5000 years ago and greatest diversity of *Tritium durum L.* is found in Ethiopia (Onwueme and Sinha, 1999). The farming communities have been active curators of genetic resources and have always been able to conserve diversity of their farm produce. This has helped farmers to ensure food security to a greater extent. Subsistence farmers living in the highlands and mid-altitude areas of Ethiopia widely cultivate major crops such as wheat and barley but the crops suffer from year to year decline in productivity. The low yield of wheat in Ethiopia (about 1.3 t/ha) is primarily due to depleted soil fertility (Asnakew *et al*., 1991), low level of chemical fertilizer usage (Asnakew *et al*, 1991; Amsal *et al*,.1997; CSA, 2000), and the unavailability of other crop management inputs (Asnakew *et al*., 1991). The productivity of wheat in Wolaita Zone (1 t/ha) (Personal Communication) is even less than the national average yield, as stated above, as result of depletion of major nutrients such as N, P and K, lack of optimum fertilizer rates, etc. One of the solutions to alleviate the problem could be applying NP fertilizers from external sources based on recommended rate for the crop. Application of fertilizers in a recommended amount is essential for high yield and quality of grains. The use of fertilizers is considered to be one of the most important factors to increase crop yield per unit area basis (Khan *et al*., 2003). Nitrogen and Phosphorus are the major nutrients affecting wheat yield and quality (Bacon, 1995). Yields of cereals have been reported as being roughly proportional to the amount of N applied (Greenwood, 1981). Increased yield of the wheat occurs on all soils with increased N rate, but such increases are reported more frequently on heavy clay soils (Sylvester-Brediey *et al*., 1984). Several reports have also indicated that increased usage of nitrogen fertilizer is considered to be a primary means of increasing wheat grain yield in Ethiopia (Asnakew *et al*., 1991; Amsal *et al*., 1997). Ayoub *et al*. (1994) reported that split application of increased N rates optimized yield and baking quality of bread wheat. In general, biomass yields of wheat were increased by N application (Amanuel *et al*., 1991).

Although nitrogen is generally the most limiting nutrient for crop production, soils are also low in available phosphorous (Schulthesis *et al*., 1997). P promotes the development of root system, seed formation, hastens ripening. Therefore, in order to stimulate early growth and development, care should be taken to provide the crop with a sufficient amount of available P (Tisdale *et al*., 1993)**.** Plants deficient in phosphorus are stunted and in contrast to those lacking nitrogen, are often dark green colors. Deficiency of P in wheat caused reduced tillering, reduced leaf area and increased susceptibility to number of diseases. Besides, maturity is often delayed in P deficient plants as compared to plants containing abundant phosphate (Marschner, 1995). Nutrient rate experiment done in Hosanna area in response of wheat to NP fertilizers shown that 20 kg P/ha and 115 kg N/ha is generally optimum for better yield of wheat (Personal Communication). However, the response to fertilizer and rates of applications vary widely with location, climate and soil type (Hartmann *et al*., 1988). Therefore, site specific nutrient rate experiment is needed to give site specific recommendation for the production of the crop. In addition, no experimental information is available in response of wheat to NP fertilizers in Wolaita Zone including the study area. Therefore, this research was initiated with the objectives to evaluate productivity of wheat in response to NP fertilizers and to identify the most suitable NP rates for production of wheat in the study area.

MATERIALS AND METHODS

The field trial was conducted at farmer's field at Kokate Mara Chare Kebele, Sodo Zuria Woreda, Wolaita Zone of South Ethiopia in the main rainy season of 2014. In the site, there is established Farmers' Research and Extension Group (FRG) consisting of 15 farmers. The experiments was conducted in one selected farmer' field. The research site is found in the altitude ranging between 2243 m.a.s.l, at 385 km from Addis Ababa. The average annual rainfall of the woreda is 1200 mm, and its minimum temperature is 14.3^{o}C and its maximum temperature is 25.6^{o}C.

Treatments and Experimental Design

Five levels of nitrogen (0, 46, 69, 92 and 115 kg ha^{-1}) and phosphorous (0, 10, 20, 30 and 40 kg ha^{-1}) were used to evaluate productivity of wheat under participatory approach by using FRG. Wheat variety "Digalo" was used for the experiment in a factorial Randomized Complete Block Design (RCBD) with three replications. Size of each plot was 4m^2 (2m x 2m). The spacing between plots and blocks were 0.50m, respectively. Triple superphosphate (TSP) was used as source of phosphorous (P) and all doses were applied at sowing time. Urea was used as source of nitrogen (N) and was applied by split application (half at planting and the remaining half was applied at mid tillering stage). All cultural practices such as weeding, hoeing, etc. were kept uniform for all treatments.

Data Collection

Agronomic Data

Growth parameters, yield components, biological yield, grain yield and straw yield data were collected.

Soil Data

Soil samples from depth of 0-30 cm were taken from the experimental field before sowing the crop for analysis of soil texture, pH, available P, total N, OC (Organic Carbon) and cation exchange capacity (CEC) following standard laboratory procedures as outlined by Sahlemedhin and Taye (2000).

Farmers Participation in stand evaluation

After giving the awareness creation in depth to the selected farmers on importance of their involvement in the research, they were grouped into three and each group was assigned to one replication for stand evaluation at crop physiological maturity stage. Farmers' used their own criteria viz. lodging intensity, expected grain yield, etc. Each group had a secretary and after a number of round way trips on assigned replication coupled with a hot discussion, they came up with common ranking preferences. Finally, each group presented its preference to other participants. The preference of each group, total summary and average preference rank of FRG farmers is indicated on table 5. To summarize all rankings, tally method was used in which the first, second, third, fourth and fifth ranking had weighted value of five, four, three, two and one points, respectively.

Economic Analysis

Economic analysis was done using partial budget analysis method. The field price of 1 deci ton (dt) of grain yield of wheat that the farmer receives was 500 Ethiopian Birr (ETB). N was applied as urea and its price was 11 ETB kg^{-1}. The gross benefit was calculated as grain yield in deci ton (dt) × field price that farmer receives from sale of crop. Finally, net benefit was calculated by subtracting total variable cost from the gross benefit.

Data Analysis

The data collected were analyzed using the general linear model of Statistical Analysis System software (SAS) and means were compared using LSD at probability level of 5%.

RESULTS AND DISCUSSION

Selected Physico-chemical Properties of Experimental Soils

The result of soil analysis indicated that the experimental soil was clay in its texture (Table 1). The pH of soil was 6.76 (Table 1) which is favourable for maximum availability of P according to Havlin *et al.* (1999). The available P content experimental soil which was 40.50 mgkg^{-1} (Table 1), could be classified as very high according to Pushparajah (1997) who classified the range of available P <11, 11-20, 20-30 and > 30 mgkg^{-1} as low, medium, high and very high respectively. The very high content of P might be due to the favourable range soil pH. The result of P content of the study site might also be attributed to the high content of organic matter of the soil.

Table 1. Selected physic-chemical properties of experimental soils before treatment application Kokate Mara Chare, in 2014

Texture	pH (H_2O)	Available P (mgkg^{-1})	Total N (%)	OC (%)	CEC (cmol (+) kg^{-1})
Clay	6.76	40.50	0.17	2.13	24.27

Table 2. Plant height (cm), Spike length (cm) Total number of tillers per plant (No.), Total number of productive tillers per plant (No.), Number of Spikelets per Spike (No.) and Number of Seeds per Spike as affected by NP application at Kokate Mara Chare, in 2014

	Plant height	Spike Length	Total number of Tillers per plant	Number of Productive Tillers per plant	Number of Spikelets per Spike	Number of Seeds per Spike
Nitrogen	***	***			*	
0	89.36b	5.00c	2.32	1.26	16.47b	50.29
46	88.50b	5.17bc	2.31	1.25	17.62b	50.97
69	100.55a	5.50a	2.32	1.25	17.19a	52.13
92	99.13a	5.45a	2.34	1.26	16.91ab	52.15
115	98.08a	5.31ab	2.31	1.25	16.94ab	51.79
LSD (5%)	4.23	0.23	NS	NS	0.50	NS
Phosphorous						*
0	94.29	5.26	2.32	1.26	16.43	50.94bc
10	95.53	5.24	2.31	1.25	16.77	51.75ab
20	93.74	5.20	2.33	1.25	16.97	50.11c
30	94.47	5.28	2.31	1.26	17.00	51.72ab
40	97.59	5.46	2.32	1.26	16.95	52.81a
LSD (5%)	NS	NS	NS	NS	NS	1.59
N*P	NS	*	NS	*		**
CV	6.06	5.97	1.78	1.34	4.08	4.20

Values followed by the same letter (s) within a column are not significantly different at P≤0.05. NS-not significant.

The total N content of the experimental soils which was 0.17% (Table 1) is in the low range based on the classification made by Landon (1991). The organic carbon content of the experimental soil was 2.13% (Table 1), which could be classified as high according to the classification made by Herrera (2005), who classified OC content of < 0.6% as very low, 0.6-1.16% as low, 1.16-1.74% as moderate and > 1.74% as high. The result of N content could be due to continuous cultivation of the land and cropping without applying N fertilizer or applying below the required amount. Similar result was also reported by Wakene *et al.* (2001). According to Landon (1991) CEC ranges of 5-15, 15-25 and 25-40 cmol (+) kg^{-1} are rated as low, medium and high, respectively. The CEC of experimental which was 24.27 cmol (+) kg^{-1} (Table 1) is in the medium range and is suitable for crop production.

Response of Wheat to NP fertilizers

Growth Parameters and Yield and Yield Components

Plant Height*:* Data analysis revealed that there was a very high significant (p<0.001) effect of N application on plant height of wheat. The tallest (100.55cm) and the shortest (88.50cm) plant height were recorded from 69 kg N ha^{-1} and 46 kg N ha^{-1}, respectively (Table 2). Application of 69 kg N ha^{-1} significantly increased the plant height by 13.62% over the 46 kg N ha^{-1} application. Statistically non significant differences among P rates on plant height were recorded. However, the highest plant height (97.59 cm) was obtained from plot that received 40 kg P ha^{-1}. Besides, N and P interaction was not significant on plant height (Table 2).

Spike Length

Data regarding spike length revealed that applied N resulted in very highly significant variation (p<0.001) on spike length of wheat (Table 2). The longest spike length (5.50 cm) and the shortest (5.00cm) spike length were recorded from 69 kg N ha^{-1} and control, respectively (Table 2). Besides, N and P interaction was also significant on spike length of the crop. However, applied P was not significant on spike length of the crop (Table 2).

Total number of tillers per plant

Statistical analysis indicated that N application had no significant effect on total number of tillers per plant (Table 2) although its value was highest (2.34) at 92 kg N ha^{-1} and lowest (2.31) at 46 kg N ha^{-1} and 115 kg N ha^{-1}. Similarly, total number of tillers per plant had no significant response to the applied P and NP interaction (Table 2).

Total number of productive Tillers

Statistical analysis of the data indicated that N and P application had no significant effect on total number of productive tillers per plant (Table 2). However, NP interaction showed a significant effect on total number of productive tillers per plant as can be seen from Table 2.

Number of Spikelets Per Spike and Number of Seeds Per Spike

Application of N significantly influenced number of spikelets per spike and its value was highest (17.62) at 46 kg N ha^{-1} and lowest (16.47) at the control. However, P application and NP interaction did not significantly influence number of spikelets per spike (Table 2). N application did not significantly affect number of seeds per spike. 52.15 was the highest number of seeds per spike obtained from 92 kg N ha^{-1} rate of application whereas 50.29 is the lowest number of seeds per spike obtained from the control. However, P application significantly influenced number of seeds per spike. Similarly, number of seeds per spike also showed a highly significant influence to the N and P interaction (Table2).

Grain yield and Thousand Seed Weight

Application of N had very highly significantly ($p<0.001$) affected grain yield of wheat (Table 3).

Table 3. Total biomass (dt ha^{-1}), grain yield (dt ha^{-1}), straw yield (dt ha^{-1}) and thousand seed weight (g) of wheat as affected by NP application at Kokate Mara Chare, in 2014

	Total Biomass	Gain Yield	Straw Yield	Thousand Seed Weight
Nitrogen	***	***	***	
0	28.01c	8.73c	19.27c	33.42
46	59.02b	18.02b	41.01b	33.53
69	86.08a	27.14a	58.95a	34.32
92	92.47a	30.35a	62.13a	34.16
115	92.48a	30.21a	62.27a	34.06
LSD (5%)	10.38	4.41	6.47	NS
Phosphorous				
0	70.40	23.84	46.56	33.94
10	72.54	22.62	49.91	34.08
20	72.66	23.74	48.92	33.77
30	70.64	22.01	48.64	33.87
40	71.83	22.24	49.59	33.83
LSD (5%)	NS	NS	NS	NS
N*P	NS	NS	NS	NS
CV	19.73	26.26	18.09	2.97

Values followed by the same letter (s) within a column are not significantly different at P≤0.05.
NS-not significant

Table 4. Partial budget analysis for N treatments in the form of Urea fertilizer at Kokate Mara Chare, in 2014

Parameters (Urea Fertilizer)	0	100	150	200	250
Grain Yield (dt/ha)	8.73	18.02	27.14	30.35	30.21
Grain income (@ 500 birr/dt)	4365	9010	13570	15175	15105
Cost of Urea (11birr/kg)	0	1100	1650	2200	2750
Total Variable Cost	0	1100	1650	2200	2750
Net Benefit (Birr/ha)	4365	7910	11920	12975	12355
Benefit: Cost		7.19	7.22	5.90	4.49

N application at all rates resulted in significantly higher grain yield over the control. The highest grain yields (30.35 dt ha^{-1}) was obtained from the application of 92 kg N ha^{-1} whereas the lowest grain yields (8.73 dt ha^{-1}) was obtained from the control. However, except the control and 46 kg N ha^{-1}, all rates of N application were statistically at par with each other (Table 3). Several authors also reported similar results to application of N on yield of wheat (Asnakew *et al*., 1991; Amsal *et al*., 1997). Data regarding P application and its interaction with N however did not show significant influences on grain yield of wheat (Table 3). Similarly, non significant responses were obtained on thousand seed weight of the grain due to applied N, P and their interactions (Table 3).

Total biomass and straw yield

The results of the experiment conducted in the study area indicated that levels of N had a very highly significant ($p<0.001$) effect on total biomass yield of wheat (Table 3). All rates of applied N produced a significantly higher total biomass yield of wheat compared to the control (Table 3). The highest total biomass (92.48 dt ha^{-1}) was obtained from 115 kg N ha^{-1} whereas the lowest total biomass (28.01 dt ha^{-1}) was obtained from the control. Similarly, Amanuel *et al*. (1991) also reported a significant response of biomass yield to the application of N on wheat. The results of the experiment however indicated that the total biomass of wheat was not significantly influenced by applied P and its interaction with N (Table 3). Similar to response of total biomass to N application, straw yield also showed a very highly significant ($p<0.001$) response to the N application. N application at all rates resulted in significantly higher straw yield over the control (Table 3). 115 kg N ha^{-1} application gave the highest straw yield which was 62.27 dt ha^{-1} whereas the control resulted in the lowest straw yield which was quantitatively about 19.27 dt ha^{-1}.

However, N application and its interaction with P had no a significant effect on straw yield of wheat (Table 3).

Partial Budget Analysis

The economic analysis conducted taking the value of grain yield into consideration indicated that the highest net benefit was obtained from application of N at the rate 92 kg ha^{-1} followed by 115 kg ha^{-1} (Table 4).

Farmers' Crop Stand Evaluation during the Experiment

Farmers' evaluation result revealed that most of the participating farmers preferred application of 92 kg N ha^{-1} and 0 kg P ha^{-1} (Table 5). The farmers' evaluation during the research indicated that application of N/P at the rates 92/0, 92/10 and 69/40 kg ha^{-1} preferred as 1st, 2nd and 3rd rank, respectively (Table 5). Lodging intensity, expected grain yield, etc., were the most frequently indicated justifications for selecting treatments in the field. This suggests that FRG approach has some positive effects on extension process due to farmers' better understanding of scientific data.

Table 5. Summary of farmers' preference during stand evaluation of crop at Kokate Mara Chare, in 2014

Treatment	NP rate Combination (kg/ha)	Farmers Preference				
		Group 1	Group 2	Group 3	Total Point	Average Ranking
N1P1	0/0	0	0	0	0	
N1P2	0/10	0	0	0	0	
N1P3	0/20	0	0	0	0	
N1P4	0/30	0	0	2	2	
N1P5	0/40	0	1	0	1	
N2P1	46/0	2	2	1	5	
N2P2	46/10	2	2	3	7	
N2P3	46/20	0	0	2	2	
N2P4	46/30	0	3	0	3	
N2P5	46/40	0	2	1	3	
N3P1	69/0	0	3	0	3	
N3P2	69/10	0	0	0	0	
N3P3	69/20	0	2	0	2	
N3P4	69/30	2	0	2	4	
N3P5	69/40	3	3	4	10	3rd
N4P1	92/0	5	4	5	14	1st
N4P2	92/10	3	4	5	12	2nd
N4P3	92/20	2	0	0	2	
N4P4	92/30	2	2	2	6	
N4P5	92/40	2	3	3	8	5th
N5P1	115/0	3	3	3	9	4rth
N5P2	115/10	2	2	1	5	
N5P3	115/20	3	2	1	6	
N5P4	115/30	2	2	3	7	
N5P5	115/40	3	3	3	9	4rth

Furthermore, participation of farmers is helpful in order to bring more precise information during research output applicability to wider context.

Conclusion and Recommendations

The study revealed that application of N fertilizer in optimum amount is very important for production of wheat in the study area. Accordingly, in the study area, application of nitrogen (N) fertilizer had very highly influenced total biomass, grain and straw yields of wheat but the effect of P and its interaction with N were not significant on these parameters. The highest grain yield (30.35 dt ha^{-1}) was obtained from the application of 92 kg N ha^{-1}. The economic analysis conducted by taking the grain yield into account revealed that the highest net benefit was obtained from the application of 92 kg N ha^{-1} and 0 kg P ha^{-1}. Farmers' crop stand evaluation result also indicated that most of the participating farmers preferred application of 92 kg N ha^{-1} and 0 kg P ha^{-1}. Therefore, application of 92 kg N ha^{-1} is recommended for production of wheat at Kokate Mara Chare. Based on the current finding, application of P for production of wheat at Kokate Mara Chare is not required. However, periodic checking of P status of soil and crop response to it is important.

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