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Research Note:

Optimizing wheat productivity through improved techniques for *in situ* moisture conservation in a micro watershed under sub-tropical region of North-Western India

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ABSTRACT

The sub-montane rainfed region of North-West India has sloping topography, poor soil structure, deep water table and suffers from uneven distribution of rainfall in space and time. In an on-farm experiment on wheat conducted in the foothill region of Punjab, soil moisture storage increased to 7.7, 12.8 and 15.4 % in treatment T_2 (minor land shaping + NPK), T_3 (T_2 + 25 % N replacement through FYM) and T_4 (T_3 + ridge sowing + Zn + herbicides), respectively, over T_1 (farmers' practice as control). Maximum increase in plant height of 28.7 per cent was observed in T_4 followed by 19.9 % in T_3 and 13.6 % in T_2 treatment compared to T_1. Number of grains per ear increased by 14.6, 25.1 and 33.7 % through T_2, T_3 and T_4 treatments, respectively over that in treatment T_1. The grain and straw yield of wheat significantly increased by 38.6 and 65.3 % in T_2, 56.3 and 76.6 % in T_3 and 63.3 and 88.2 % in T_4 treatment respectively over T_1 treatment (control). Maximum monetary returns were obtained in T_4 treatment.

Keywords: conservation, nutrient management, rainfed, soil moisture, Punjab, wheat, yield,

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INTRODUCTION

In rainfed areas, twin factors limiting crop production are moisture deficiency and low soil fertility. Spectacular increase in crop yields has been obtained by adequate application of fertilizer on rainfed crops at different places in the country (Nagre, 1981). The sub-montane rainfed region of N-W India represents one-tenth of the area of Punjab state, which suffers from uneven distribution of rainfall. The region has steep to gentle sloping topography, poor soil structure and deep water table (Sur and Ghuman, 1992). The rainfed areas are mostly underfed from the point of view of application of inputs compared to outputs obtained (Arora and Hadda, 2003). The area is more hungry than thirsty which adds to its low productivity. Mean annual rainfall of the area is 1000 + 304 mm, 80% of which is received during the summer monsoon season. The problem of high soil erosion occurs due to higher slopes and short duration but high intensity rainstorms. These rainstorms vary in their duration from as short as 0.5 hrs to as long as 22.45 hrs. Loss of organic matter, whether by erosion or high temperature in the rainfed agro-ecosystem adds to impoverishments of soil resources of several elements essential for plant growth.

However, the challenge of improving productivity in rainfed areas, can be addressed by proper management of natural resources, efficient utilization of nutrients and in-situ moisture conservation (Hadda *et al.*, 2005). One of the ways is to use the nutrients in an integrated manner from all possible resources and maximizing the utilization of applied nutrients by crops (Acharya and Bandopadhyay, 2002). *In-situ* conservation of moisture along with fertilization may significantly increase the yield of crops through better root development and plant growth (Gupta and Bhan, 1997).

Wheat is one of the most important crops popularly grown on receding soil moisture under rainfed conditions. One of the most important factors limiting wheat production is the lack of irrigation water. Of the total area under wheat cultivation in the state, rainfed wheat accounts for more than 40 percent. The low productivity of the rainfed wheat in the region, as against national or states' average, is mainly attributed to growing of local varieties under low input. Due to poor purchasing power, farmers of the region do not follow complete package of practices in wheat cultivation.

However, there is dearth of information on the effect of improved soil moisture conservation and nutrient management practices in wheat crop from rainfed sub-tropical region of Punjab. Hence, the present investigation was conducted on light textured erosion-prone lands under sub-catchments of micro-watershed in foothill rainfed region of Punjab.

MATERIALS AND METHODS

On-farm experiments with wheat crop were initiated in cluster of villages surrounding Kokowal-Majari-Jhunewal watershed with undulating topography in District Hoshiarpur, Punjab, India.

The rainfall constitutes the major water resource of the area. A total of 547 mm rain was received during monsoon season in 2002, which was below normal. Rainfall was received in 31 rainstorms out of which 12 were more than 10 mm. These rainstorms varied in their duration from as short as 0.5 hrs to as long as 14.00 hrs. The soils of the area remain dry for 4-5 months in a year and qualify for an Ustic soil moisture regime (Sehgal and Sys, 1970). The steepness of slope on the experimental sites varied between 3 to 4 per cent. A group of 3 to 4 farmers was selected representing a single unit of land. An improved variety PBW 396 of wheat (*Triticum aestivum* L.) was sown during rabi season of 2002-03. The different imposed treatments used in the crop are : T_1=Farmers' practice (control), T_2= Minor land shaping + recommended dose of NPK, T_3=T_2 + 25 % N replacement through farm yard manure (FYM) and T_4=T_3 + ridge sowing + Zn as per recommendation + herbicides. The treatments were replicated thrice in Randomized Block Design (RBD) in a village. The recommended doses of fertilizers for wheat in the rainfed region include 80 kg N (in two splits), 40 kg P, 30 kg K ha^{-1} along with 10 kg $ZnSO_4$ per hectare where Zn is deficient/low. Applications of N, P and K were done using urea, single super phosphate and muriate of potash, respectively. The initial soil samples from the experimental sites were collected and processed for physico-chemical analysis as per standard procedures (Jackson, 1973).

The farmers' practice includes sowing conventional (local) crop varieties without following any land management and moisture conservation practices. Mostly they cultivate on rugged beds with application of only one-third of the recommended dose of nitrogenous straight fertilizer.

The periodic soil moisture sampling was done and soil moisture storage was calculated gravimetrically. The observations on plant growth parameters were recorded. Dry matter yield was recorded by taking five plants randomly from each plot and then air-dried followed by oven drying at 65±1ºC until constant weight was reached. The grain and straw of the harvested mature crop were separated and the economic yield was recorded from each treated plot. The grain yield was adjusted at 15% grain moisture content. The samples were then ground in Willey mill fitted with stainless steel blades. Nitrogen content of plant samples was estimated by Microkjeldahl distillation method (Jackson, 1973). The plant material was digested with nitric, sulphuric and perchloric acid mixtures. Phosphorus concentration in extract was determined by vanadomolybdo phosphoric acid yellow colour method while potassium content in the extract was determined using flame photometer (Tandon, 1995). After harvest, the soil samples were also collected from each plot and analysed for NPK and Zn content as per the standard procedures. The results were analyzed statistically using randomized block in the experiment (Cochran and Cox, 1957).

RESULTS AND DISCUSSION

Physico-chemical properties of the soils

The soils of the experimental sites are medium to coarse in texture with low to medium moisture retention capacity and available nutrients. The pH of the soils varied from 7.7 to 8.4 with a mean value of 8.2 and electrical conductivity from 0.14 to 0.28 dS m^{-1} with mean of 0.20 dS m^{-1}. The organic carbon content varied from 0.22 to 0.45 per cent with a mean value of 0.30 %. The soils were low in their available N (92.4 to 170.0 kg ha^{-1}), low to medium in available P (6.2 to 8.5 kg ha^{-1}) and medium to high in available K (139.5 to 232.4 kg ha^{-1}). Available Zn varied from 0.36 to 0.85 mg kg^{-1} soil.

In-situ soil moisture storage

Soil moisture storage at 30 days after sowing (DAS), increased by 12.9, 20.0 and 25.9 % in T_2, T_3 and T_4 treatments, respectively, over that treatment

Table 1. Effect of different treatments on soil moisture storage

Treatments	Moisture storage at 30 DAS (cm/120 cm)	Moisture storage at 60 DAS (cm/120 cm)
T_1	8.5	7.8
T_2	9.6	8.4
T_3	10.2	8.8
T_4	10.7	9.0

T_1 (Table 1). However, at 60 DAS, soil moisture storage increased to 7.7, 12.8 and 15.4 % in T_2, T_3 and T_4 treatments, respectively compared to that in the farmers' practice (T_1). The increase in soil moisture content may be attributed to better soil management through land shaping and leveling. Also, application of manure increased soil moisture retention (Hadda *et al*., 2005). Less soil disturbance like minor land leveling also resulted to moisture conservation and increase profile moisture storage to 21-mm/90 cm over that of the farmers' practice (Singh, 1995).

Growth and yield attributes of wheat

Plant height at 90 days after sowing (DAS) increased significantly in all the applied treatments than that in farmers' practice (Table 2). Increases of 28.7 % in T_4, 19.9 % in T_3 and 13.6 % in T_2 were observed compared to that in T_1. Increase in plant height of wheat was also attributed to land configuration and nutrient management under limited water supply (Shivakumar and Mishra, 2001). Application of FYM to wheat as well as inorganic fertilizer at recommended levels increased plant height (Rameshwar and Singh, 1998; Arora and Hadda, 2003). This plant reaction was attributed to higher availability of nutrients in soil as compared to farmers' practice. At maturity, the number of grains per ear also increased in all the treated plots. The increase was observed to be 14.6, 25.1 and 33.7 % in T_2, T_3 and T_4, respectively, compared to that in T_1. Integrated soil management enhanced root growth and better uptake of water and nutrients and consequently, developed taller plants and more number of ears per plant (Sharma and Acharya, 1987). The effect of treatments on the weight of 1000 grains also showed a similar trend. The

Table 2. Effect of different treatments on plant parameters

Treatments	Plant height at 90 DAS (cm)	Number of grains per ear	Ear length (cm)	1000 grain weight (g)
T_1	61.83	23.14	5.88	41.03
T_2	70.24	26.53	6.72	42.02
T_3	74.11	28.93	7.26	42.80
T_4	79.55	30.94	7.80	43.54
LSD (P=0.05)	0.20	0.23	0.12	0.18

difference in increase 1000-grain weight was 2.5, 1.8 and 1.0 g in T_4, T_3 and T_2 treatments, over that in treatment T_1 (Table 2). Significant improvement in the wheat plant parameters over control was noted with the consequence of improvement in soil conditions and due to additional nutrients supplied through FYM in imposed treatments (Pawar and Sharma, 2001).

Dry matter accumulation

With the application of different treatments, the dry matter per plant increased significantly both at 60 DAS and at the time of harvest. Dry matter per plant was 1.7 and 5.4 g at 60 DAS and at harvest, respectively, in T_1 treatment. It increased up to a maximum of 3.1 and 10.6 g per plant under treatment T_4 (Table 3). The manure (FYM) incorporation, besides influencing the soil physical properties, increases nutrient availability and conserved soil moisture which are added benefits especially for rainfed agriculture (Arora and Hadda, 2003). Dry matter accumulation of wheat was also observed by Rameshwar and Singh (1998) with the application of organic and inorganic fertilizers at recommended levels in field experiments.

Grain and straw yields of wheat

The significant increase in grain yield of wheat was observed with the application of different moisture conservation and nutrient management treatments over the farmers' practice. The grain yield of wheat was higher by

Table 3. Effect of different treatments on yield of wheat

Treatments	Dry matter per plant (g)		Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)
	60 DAS	At harvest			
T1	1.68	5.42	1270	2220	36.3
T2	2.33	7.95	1760	3670	32.4
T3	2.79	9.54	1985	3920	33.6
T4	3.14	10.62	2075	4180	33.2
LSD (P=0.05)	0.04	0.12	28	19	NS

38.6 % in T_2, 56.3 % in T_3, and 63.3 % in T_4 than the farmers' practice (T_1) (Table 3). The straw yield also increased significantly to 65.3, 76.6 and 88.2 %, when subjected to T_2, T_3 and T_4, respectively, compared to control (farmers' practice, T_1). However, maximum grain and straw yields were observed under treatment T_4 that was 2,075 and 4,180 kg ha^{-1}, respectively. The increase in grain and straw yields with the imposed treatments may be due to application of inorganic and organic fertilizers. The availability and enhanced absorption of nutrients caused more cell elongation and development and also root development which ultimately increased growth and yield of the crop.

The presence and conservation of moisture is known to help in photosynthesis, fertilization of flowers, seed setting, protein synthesis and nitrogen metabolism thus, improve the yield of wheat. In T_4, application of zinc may also have played a role in improving grain and straw yields by acting as a catalyst or stimulant in most of the physiological and metabolic processes of the plant (Patel *et al*., 1995).

A significant positive correlation between grain yield and number of grains per ear, ear length and test weight (r= 0.98, 0.97 and 0.96, respectively) was observed. This confirms that grain yield of wheat is dependent on growth and yield attributes of the crop. Significant increase in grain and straw yield of wheat was also observed with the application of fertilizers and FYM under

Table 4. Total nutrient uptake by wheat

Treatments	Nitrogen uptake ($kg\ ha^{-1}$)	Phosphorus uptake ($kg\ ha^{-1}$)	Potassium uptake ($kg\ ha^{-1}$)
T_1	30.88	4.52	27.47
T_2	50.47	6.79	49.82
T_3	62.19	8.86	58.90
T_4	69.52	10.10	64.93
LSD (P=0.05)	7.20	2.14	6.52

rainfed conditions (Pawar and Sharma, 2001) and Totawat *et al*. (2001) on Typic Haplustafs of Rajasthan. Increase in grain and straw yields with nutrient management and in-situ moisture conservation treatments in rabi crop was also observed by Patil and Sheelavantar (2000) in the semi-arid tropics. Highly significant correlation existed between soil moisture storage at 30 and 60 DAS with grain yield of wheat (r = 0.98 and 0.99) and straw yield of wheat (r= 0.97 and 0.96). Straw yield was found to be totally in order of dry matter accumulation at 60 DAS (r= 0.95) and at harvest (r=0.96).

The harvest index was not affected significantly as both grain and straw yield were proportionately higher due to the imposed treatments (Table 3).

Nutrient uptake by wheat

The total uptake of nitrogen, phosphorus, and potash in wheat was found to be significantly higher in treatments T_2, T_3, and T_4 than T_1 (Table 4). The N uptake increased by 63.4, 101.4 and 125.1 per cent, while P uptake increased by 50.2, 96.1 and 123.4 per cent and K uptake in grain and straw of wheat by 81.4, 114.4 and 136.4 per cent in T_2, T_3, and T_4 treatments respectively over that in treatment T_1 (Farmers' practice). The increase in nutrient uptake indicated that wheat required a continuous liberal supply of major nutrients to meet an accelerated demand for potential yield realization on the soils of average productivity (Tiwana *et al.*, 1999). Also, adequacy of moisture and congenial temperature by application of manure might have helped in better utilization of nutrients. Similar increase in nutrient uptake by wheat was observed by Rameshwar and Singh (1998). Arora and Hadda (2003) also observed increase

Table 5. Effect of treatments on economic of wheat production

Treatments	Net returns (Rs ha^{-1})	B:C ratio (Rs Re^{-1})
T_1	2148	1.32
T_2	3724	1.51
T_3	3825	1.54
T_4	4013	1.61
LSD (P=0.05)	–	0.12

in nutrient content in grain and straw of wheat with the application of recommended doses of fertilizers and in-situ moisture conservation treatments. Grain and straw yields were significantly and positively correlated with N uptake (r= 0.99 and 0.97), P uptake (r= 0.97 and 0.94) and K uptake (r=0.99 and 0.98) of the wheat plant.

Soil fertility after harvest

After harvest of the wheat crop, the soil samples collected from the experimental plots showed that the pH and EC values ranged between 7.5 to 8.5 and 0.17 to 0.34 dS m^{-1}, respectively. The organic carbon content ranged between 0.32 and 0.52 per cent indicating a slight build up with the application of FYM. Similarly, available N, P and K content in soils varied from 88.7 to 178.0, 6.6 to 8.4 and 140.6 to 241.3 kg ha^{-1}. Zinc content also found to be slightly higher than initial with the range from 0.34 to 0.92 mg kg^{-1} soil.

Monetary returns

The data indicated that the maximum profit of Rs. 4013 ha^{-1} (US$ 100 ha^{-1}) was obtained with treatment T_4 imposed in wheat. Benefit cost ratio (Rs Re^{-1}) was 14.4, 16.7 and 21.9 % higher in T_2, T_3 and T_4, respectively compared to T_1 (Table 5). The highest benefit cost ratio value (Rs. 1.61 Re^{-1}) was obtained when wheat was grown on leveled land on ridges with recommended dose of fertilizers (25 % N replaced through FYM) and herbicide application (T_4). This suggests that there is a need to follow these practices to improve the yields and consequently, the income of the farmers in the rainfed area. Panday *et al.* (2001) concluded that inclusion of any production factor in farmers' practice gave more gross as well as net returns. Similar observations were reported by Rana *et al*. (1986).

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