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Soil and nutrient management practices for sustaining crop yields under maize-wheat cropping sequence in sub-mountain Punjab, India

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Abstract

Soil as well as nutrient management is essential for obtaining sustainable crop yields under maize–wheat cropping sequence in rain-fed sub-mountain region of Punjab. The area, suffers from ill distribution of rainfall in space and time, have steep to very steep topography and deep to very deep water-table. Field experiments were conducted on undulating terrain using participatory approach on farmers' fields in five selected villages in District Hoshiarpur of Punjab, India to evaluate soil and nutrient management practices. The significant increase in grain yield of wheat was observed with the application of different soil and nutrient management practices over the farmers' practice with a maximum of 34 per cent. Soil moisture storage increased by 12, 30, 35 and 45 per cent with shallow tillage, deep tillage, recommended dose of fertilizers (RDF, 75%) + FYM and raised-bed sowing, respectively, compared with the farmers' practice. Raised-bed sowing, RDF (100%), RDF (75%) + FYM and deep tillage showed an increase of 52, 55, 57 and 37 per cent in height of maize plant over the farmers' practice at 60 days after sowing. There was also significant increase in plant girth of maize in all the imposed treatments over farmers' practice. The study showed that adoption of improved moisture conservation practices coupled with optimum inorganic fertilizer use along with organic manure helps in improving the crop yields of the rain-fed areas.
Key words: Soil management, nutrient, maize, wheat, yield, moisture, storage

Introduction

The rain-fed agriculture has a distinct place in Indian agriculture, occupying nearly 68 per cent of cultivable area and contributing 44 per cent to the food grain production. The rain-fed sub-mountain region of Punjab, India, covers about 10 per cent of the total area of the state. The area suffers from ill distribution of rainfall in space and time. The region has steep to very steep topography and deep to very deep water table. The rain-fed areas are mostly underfed from the point of view of application of inputs compared to outputs obtained.

The soils of the region are structurally unstable, poor in organic carbon and nutrients, and the lands have undulating topography resulting in non-uniform moisture distribution. Thus, there is need to conserve soil moisture for improving crop yields in the area. The area is more hungry than thirsty which further adds to its low productivity. Loss of organic matter whether by erosion or high temperature in the rain-fed agro-ecosystem adds to impoverishment of soil resources of several elements essential for plant growth. However, the challenge of improving productivity in rain-fed areas can be addressed by efficient utilization of nutrients and natural resources. 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). It, therefore, requires the development of need-based location- specific technologies to ecologically rehabilitate and obtain the production-potential on a sustained basis. Soil and nutrient management practices are of paramount concern to conserve moisture, improve the productivity and reduce the menace of erosion in the sub-mountain Punjab (Arora and Hadda, 2003). Keeping these points in view, a study was conducted to evaluate soil (viz. shallow tillage, deep tillage and sowing of maize on raised beds) and nutrient management practices (viz. use of chemical fertilizers along with organic manures) in maize–wheat cropping sequence on farmers' fields at five villages of district Hoshiarpur in sub-mountain Punjab, India.

Materials and methods

On-farm trials were conducted in villages Kokowal, Majari, Jhunewal, Dallewal and Binewal located in District Hoshiarpur of sub-mountain Punjab, India. In-situ soil moisture conservation and integrated nutrient management practices were evaluated on growth and yield of the maize and wheat crops.

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The total recorded rainfall during the crop year 2001-02 was 705 mm, considering only those rainstorms which produced minimum of 10 mm or more of rainfall in single rainstorm. The annual rainfall occurred in 27 rainstorms with minimum of 10 mm and maximum of 86 mm of rainfall. These rainstorms varied in their duration from as low as 0.5 hrs to as high as 22.45 hrs. The steepness of slope on the experimental sites varied in between 2 to 4 per cent. The soils are medium to coarse in texture (sandy loam to loamy sand), with low to medium in moisture retention capacity and available nutrients. The important characteristics of the soils are presented in Table 1.

Table 1. Characteristics of soils of experimental area.

Soil characteristics	Range	Mean
pH (1:2.5)	7.8- 8.4	8.2
EC (1:2.5) (dS m^{-1})	0.12- 0.24	0.18
Organic carbon (%)	0.18- 0.42	0.30
N (kg ha^{-1})	89.3- 162.5	130.6
P (kg ha^{-1})	5.6- 8.2	6.8
K (kg ha^{-1})	136.7- 220.8	181.5
DTPA – Zn (mg kg^{-1})	0.38-0.46	0.42
Bulk density (Mg m^{-3})	1.43 – 1.54	1.49
Total soil porosity (m^3 m^{-3})	0.40 – 0.45	0.42

A group of 3 to 4 farmers were selected representing a single unit of land in each village. Here Farmers' practice is very much conventional without any improved land and soil moisture conservation practice. Mostly farmers add whatever available farm yard manure during wheat and tillage at irregular depths during both the crops. Farmers generally apply only urea at 25 days after sowing in maize and with first showers of winter rains in wheat, that too much below the recommended doses. They generally sow the crop on flat bed and along the slope.

Wheat variety PBW-396 and maize variety "Prakash" was sown in rabi 2001-02 and kharif 2002 season, respectively. In-situ soil moisture conservation treatments included shallow tillage (T_2), deep tillage (T_3) and raised-bed sowing (T_4) which were compared with farmers' practice (T_1). The integrated nutrient management treatments included application of recommended dose of fertilizers (RDF) 100 % (T_5) and RDF (75%) + farm yard manure (FYM) at 10t ha^{-1} (T_6) with shallow tillage practice, as it is feasible and economical. The treatments were replicated thrice in randomized block design (RBD) in a village. The recommended doses for wheat in the rain-fed region included 80 kg N, 40 kg P, 30 kg K ha^{-1} along with 10 kg $ZnSO_4$ per hectare where Zn is deficient/low. In case of maize, recommended doses are 125 kg N, 60 kg P, 30 kg K, 10 kg $ZnSO_4$ per hectare along with 10-12 t FYM ha^{-1}. In the present experiments, N, P, K and Zn were applied through urea, single super phosphate, muriate of potash and zinc sulphate, respectively. Farm yard manure was applied at the rate of 10 t ha^{-1} in the respective treatment. The periodic observations on soil moisture samples, plant girth and plant height were taken. The crop was harvested at maturity from each plot and the grains were separated and their yields were recorded.

Results and discussion

Soil Moisture

Soil moisture storage at 30 days after sowing (DAS) increased by 12, 30 and 45 per cent with shallow tillage, deep tillage and raised bed sowing treatments, respectively, over the farmers' practice. The soil moisture storage observed was more in sub-surface layers (15-90 cm) at 30 DAS in comparison to surface (0-15 cm) layers in the imposed treatments (Table 2). However, in treatment T_6 i.e. application of RDF (75%) + FYM

Table 2. Effect of different treatments on soil moisture storage (120 cm depth) in wheat crop at 30 and 60 days after sowing (DAS).

	30 DAS		60 DAS	
	cm	% increase over T_1	cm	% increase over T_1
T_1 : Farmers' practice	10.0	-	21.2	-
T_2 : Shallow tillage	11.2	12.0	23.2	9.43
T_3 : Deep tillage	13.0	30.0	23.9	12.74
T_4 : Raised bed	14.5	45.0	24.7	16.51
T_5 : T_2+RDF (100%)	11.8	18.0	21.5	0.01
T_6 : T_2+RDF (75 %) + FYM at 10 t ha^{-1}	13.5	35.0	24.0	13.21
CD (5%)	1.32		1.45	

at 10 t ha^{-1} moisture storage was 35 % higher over farmers' practice which may be because application of organic manure is known to retain more moisture due to rains in the area. At 60 DAS, soil moisture storage increased to the tune of 9.4, 12.7, 16.5 and 13.2 per cent with shallow tillage, deep tillage, raised bed sowing and application of RDF (75%) + FYM at 10 t ha^{-1} treatments, respectively, over the farmers' practice (Table 2). The increase in soil moisture content may be because of minor land shaping, tilling to depth and sowing of crop across the slope.

Plant height and girth

In Kharif, plant height of maize at 60 DAS increased in all the imposed treatments compared with farmers' practice (Table 3). Maximum increase of 57.0 per cent in plant height was observed with the application of RDF (75%) + FYM at 10 t ha^{-1} treatment followed by 55.2 per cent increase in treatment T5, 51.7 per cent in raised-bed treatment, 37.4 per cent in deep tillage and 18.0 per cent with shallow tillage treatment than that in farmers' practice (Table 3). At 90 DAS, plant height also increased in all the treatments than that in farmers' practice. The height of maize plant was maximum to be 184.2 cm in T_6 treatment and was to the magnitude of 49.8 cm, 48.1 cm, 41.8 cm, 35.2 cm and 13.9 cm higher in T_5, T_4, T_3 and T_2 treatments, respectively, over T_1 treatment.

Plant girth both at 60 and 90 DAS was higher in imposed treatments with a maximum of 63.1 per cent in T_6 treatment, 58.3 per cent in T_5 treatment, 52.4 per cent in T_4, 40.6 per cent in T_3 and 23.5 per cent in T_2 treatment at 60 DAS compared with farmers' practice (Table 4). Maximum increase in girth to the magnitude of 1.1 cm was observed with the application of RDF (75%) + FYM at 10 t ha^{-1} treatments, respectively, over the farmers' practice at 90 DAS (Table 4). The increase in plant height and girth may be due to increased moisture storage and better uptake of nutrients supplied for normal growth of plants.

Table 3. Effect of different treatments on plant height (cm) of maize at 60 and 90 days after sowing (DAS).

	60 DAS		90 DAS	
	cm	**% increase over T_1**	**cm**	**% increase over T_1**
T_1 : Farmers' practice	82.6	-	134.4	-
T_2 : Shallow tillage	97.5	18.04	148.3	10.34
T_3 : Deep tillage	113.5	37.41	169.6	26.19
T_4 : Raised bed	125.3	51.69	176.2	31.10
T_5 : T_2+RDF (100%)	128.2	55.21	182.5	35.79
T_6 : T_2+RDF (75 %) + FYM at 10 t ha^{-1}	129.7	57.0	184.2	37.05
CD (5%)	8.50		21.13	

Table 4. Effect of different treatments on plant girth of maize at 60 and 90 DAS.

	60 DAS		90 DAS	
	cm	**% increase over T_1**	**cm**	**% increase over T_1**
T_1 : Farmers' practice	0.935	-	1.082	-
T_2 : Shallow tillage	1.155	23.53	1.460	34.93
T_3 : Deep tillage	1.315	40.64	1.835	69.59
T_4 : Raised bed	1.425	52.40	2.110	95.01
T_5 : T_2+RDF (100%)	1.480	58.29	2.182	101.66
T_6 : T_2+RDF (75 %) + FYM at 10 t ha^{-1}	1.525	63.10	2.205	103.79
CD (5%)	0.211		0.217	

Grain yield

An 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 13.9 per cent in shallow tillage, 27.0

per cent in deep tillage and about 34.0 per cent in raised bed treatment over the farmers' practice (Table 5). Application of 100 % RDF and RDF (75%) + FYM at 10 t ha^{-1} increased the grain yield of wheat by 35.6 and 42.6 per cent over the farmers' practice. Not only the grain yield but also the straw yield of wheat increased significantly to the tune of 30.2, 53.4, 56.3, 60.0 and 65.3 per cent with shallow tillage, deep tillage, raised bed sowing, 100 % RDF and 75 % RDF + FYM treatments, respectively, over the farmers' practice. Grain and straw yields of wheat observed were 15.4 and 38.3 q ha^{-1}, respectively, in raised bed treatment. However, grain and straw yield was observed to be maximum of 16.4 and 40.5 q $ha^{-1,}$ respectively, with the application of 75 % RDF + FYM, respectively, (Table 5). This was perhaps due to abundant supply of plant nutrients which increased the protoplasmic constituents and accelerated the process of cell division and elongation. This in turn increased the values of growth and yield contributing attributes which finally reflected in increased grain and straw yield of wheat (Auti et al., 1999).

There appeared to be 8.8 per cent increase in grain yield of maize in raised bed treatment, 11.2 per cent with the application of RDF (100 %) and 13.1 per cent with application of 75 % RDF + FYM as compared to farmers' practice (Table 6). Application of FYM not only known to efficiently conserve the soil moisture and better availability of nutrients but also improved the soil physical properties. Such an increase in maize grain yield through moisture conservation and nutrient management practices has also been observed in a watershed of Rajasthan state of India (Gaur, 2002). Kumar and Thakur (2004) also observed significant increase in grain yield of maize with the application of RDF along with 10 t FYM ha^{-1} in the rain-fed mid-hill region. This increase in grain yield may be attributed to application of nutrients through in-organic and organic sources and the more availability and absorption of nutrients which caused cell elongation, root development and ultimately increased growth and yield of crop (Patil and Sheelavantar, 2000). Also, the conservation of moisture has been known to help in photosynthesis, fertilization of flowers, seed setting, and protein synthesis and nitrogen metabolism thus improving the crop yields (Sakthivel *et al*., 2003).

Table 5. Effect of different treatments on grain and straw yield of wheat.

	Grain yield		**Straw yield**	
	(q ha^{-1})	**% increase over T_1**	**(q ha^{-1})**	**% increase over T_1**
T_1 : Farmers' practice	11.5	-	24.5	-
T_2 : Shallow tillage	13.1	13.91	31.9	30.20
T_3 : Deep tillage	14.6	26.96	37.6	53.47
T_4 : Raised bed	15.4	33.91	38.3	56.32
T_5 : T_2+RDF (100%)	15.6	35.65	39.2	60.00
T_6 : T_2+RDF (75 %) + FYM at 10 t ha^{-1}	16.4	42.61	40.5	65.30
CD (5%)	1.43		2.76	

Table 6. Effect of different treatments on grain yield of maize

Treatments	**Grain yield**	
	(q ha^{-1})	**% increase over T_1**
T_1 : Farmers' practice	22.70	-
T_2 : Shallow tillage	23.44	3.25
T_3 : Deep tillage	24.35	7.27
T_4 : Raised bed	24.70	8.79
T_5 : T_2+RDF (100%)	25.25	11.22
T_6 : T_2+RDF (75 %) + FYM at 10 t ha^{-1}	25.68	13.12
CD (5%)	0.67	

In conclusion, the use of improved moisture conservation practices coupled with optimum inorganic fertilizer use along with organic manure helped in improving the crop yields of the rain-fed areas in a sustainable manner.

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