Indian J. Dryland Agric. Res. & Dev. 2022 37(1): 5-9 10.5958/2231-6701.2022.00002.1

Effect of Planting Methods on Soil Moisture, Growth and Productivity of Rainfed Maize (*Zea mays* L.) - Wheat (*Triticum aestivum* L.) Cropping System in Shiwalik Foothills of Punjab, India

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ABSTRACT: A field experiment was conducted to assess the effect of different *in-situ* moisture conservation practices on plant water status, soil moisture storage; yield attributes and yield in rainfed maize-wheat cropping system at AICRP on Dryland Agriculture experimental farm, Ballowal Saunkhri during 2016-17 and 2017-18. The experiment included five treatments *viz.* deep ploughing, planting on beds 67.5 cm apart with plant to plant spacing of 18 cm, ridge sowing at 60 cm x 20 cm, conservation furrow method (after planting 4 rows at 60 cm apart 5th row is skipped) and flat sowing at 60 cm x 20 cm. Moisture conservation practices maintained higher relative leaf water content and leaf area index and also stored higher profile soil moisture for succeeding wheat crop as compared to flat sowing. In maize, *in-situ* moisture conservation practices - ridge planting, conservation furrow planting, bed planting and deep ploughing resulted in significant increase in yield of maize over flat sowing with a respective increase of 18.1, 16.2, 11.6 and 7.7 per cent. The yield of succeeding wheat crop also improved significantly in ridge planting and conservation furrow planting plots by 19 per cent and 15.7 per cent respectively over flat sowing. Highest system productivity was recorded in ridge planting (7131 kg ha^{-1}) followed by conservation furrow method (6906 kg ha^{-1}) which gave additional income of Rs 24,056 ha^{-1} and Rs. 19,656 ha^{-1} respectively over flat sowing.

Keywords: *In-situ* moisture conservation, maize-wheat cropping system, rainfed

Introduction

Maize (*Zea mays* L.) -wheat (*Triticum aestivum* L.) cropping system is one of the major cropping systems of India occupying an area of 1.83 m ha predominantly in rainfed ecologies and contributes around 3% to the national food basket after rice-wheat (32%) and rice-rice (5%) systems (Chaudhary *et al*., 2009; Saad *et al*., 2016). In the state of Punjab, maize is cultivated over an area of 0.12 million hectares (Anonymous 2019) during *kharif* (July to September) and wheat is cultivated after maize during *rabi* (November to April) over an area of 3.52 million hectares. Both these crops are cultivated under rainfed conditions in the North-Eastern foot hill parts of the Punjab known as “Kandi area”. This lower Shivalik Kandi region adjoining Himachal Pradesh covers an area of about 0.39 m ha. The characteristic features of this region are undulating topography, slopy fields, coarse textured soils with low organic carbon (< 0.3%) and poor water retention capacity, uneven distribution of rainfall and prolonged dry spells during crop period. Rainwater constitutes the major water resource and is sufficient to take two crops annually but it becomes scarce because of ill distribution in time and space. The area receives average annual rainfall of 1056 mm, out of which about 80% is received in a short span of three months (July to September) and most of the rain water is lost as runoff from the cultivated fields. Dry spells of variable length and frequency occur during the *kharif* and *rabi* seasons. Early withdrawal of monsoon is common in this region, resulting in severe drought at the time of grain formation in maize. Moreover, at the time of the sowing of wheat, probability of occurrence of rainfall is very less and the major problem in the timely establishment of spring wheat is the lack of adequate moisture in the seed zone (Sharma and Acharya, 2000). Hence, under rainfed conditions, soil moisture conservation during *kharif* season assumes more significance for ensuring successful *kharif* and *rabi* crops. The moisture stored in the soil profile is utilized by the crop during moisture deficit conditions. The most efficient and cheapest way of conserving rain water is to hold it *in-situ*. Different *in-situ* moisture conservation practices viz., ridge planting, bed planting, conservation furrow method of planting and deep tillage are being practiced and recommended for different type of soils for better conservation of moisture. But, the information on performance of various *in-situ* moisture conservation practices in maize-wheat sequence cropping system is meager; hence an experiment was conducted to evaluate the effect *in-situ* moisture conservation practices in mitigating dry spells in rainfed maize-wheat cropping system.

Materials and Methods

The field experiment was conducted during 2016-17 and 2017-18 at Punjab Agricultural University’s Regional Research Station, Ballowal Saunkhri, geographically situated 31°5.87′ N latitude 76°23.37′ E, longitude at an elevation of about 348 m above msl.

The climate of the site is sub-humid with mean annual rainfall of 1,056 mm. About 80% rain occurs in the *kharif* season (July-September) and rest 20% occurs in the *rabi* season. The total rainfall received during *kharif* 2016 and *kharif* 2017 crop growing seasons was 544.4 mm and 726.3 mm, respectively and during *rabi* 2016-17 and *rabi* 2017-18 was 202.4 mm and 113 mm, respectively. During 2016, maize crop experienced two dry spells of 10 days and 21 days at seedling and grain formation stages respectively while in 2017 dry spell of 12 days duration occurred at grain formation stage. Two dry spells of 58 days and 49 days were recorded between maize harvesting and sowing of wheat.

Soil of the experimental site was sandy loam in texture, with pH 7.9, EC 0.14 dS/m and containing 0.34% organic C, 227 kg ha^{-1} available N, 16.4 kg ha^{-1} available P and 230 kg ha^{-1} available K in the top 0-15 cm surface soil. The experiment included five treatments, viz., deep ploughing with chisel plough at 45 cm apart followed by sowing at row to row spacing of 60 cm and plant to plant spacing of 20 cm, bed planting with one row in middle of beds spaced 67.5 cm apart and plant to plant spacing of 18 cm, ridge planting at 60 cm x 20 cm with seeds placed on side of the ridge 6-7 cm above the base, conservation furrow method (after planting 4 rows at 60 cm apart 5th row is skipped and converted into furrow and seeds sown with plant to plant spacing of 16 cm) and flat sowing at 60 cm x 20 cm spacing. The experiment was conducted under rainfed conditions in randomized block design with four replications. Maize variety PMH-1 was sown on 1st July and 3rd July in respective years as per treatment using 20 kg seed per hectare, followed by wheat variety PBW 660 sown on 7th November and 6th November in respective years at a row spacing of 25 cm using 100 kg seed per hectare. Direct effect of *in-situ* moisture conservation practices was studied in maize and residual effect of moisture conservation practices in maize was studied on succeeding wheat crop. Maize was harvested on 27th September and 6th October in 2016 and 2017, respectively and wheat was harvested on 16th April and 12th April in respective years. All other recommended crop management practices from sowing to harvest were followed as per the package of practices of Punjab Agricultural University, Ludhiana for rainfed maize and wheat. Leaf area was estimated using Sunscan Plant Canopy Analyzer SS1-STD. For calculating relative leaf water content of maize leaf, samples taken during dry spell from the field were weighed for fresh weight (FW) and dipped in water for 4 hours for making them turgid. The turgid weight (TW) was recorded after taking the samples out of water and removing the surface moisture gently with filter paper. Samples are then oven dried at 80°C for 24 hr and the dry weight (after being cooled down in a desiccator) was recorded (DW). From these observations, relative leaf water content (RWC) was calculated by using formula:

$$\text{RWC (\%)} = \frac{\text{FW-DW}}{\text{(TW-DW)}} \times 100$$

where FW is fresh weight (g), TW is turgid weight (g), DW is dry weight (g).

Soil moisture was determined gravimetrically, using a core sampler. Soil cores were taken at depths of 0-15, 15-30, 30-60, 60-90, 90-120, 120-150 and 150-180 cm. Once collected, the samples were placed in air tight aluminum box and then transported immediately to laboratory to record fresh weight (W_1). Samples were then oven dried at 105ºC for 24 hours and were weighed again to determine dry weight (W_2). The moisture content on depth basis (d_W) was calculated as per the equation given below (Dastane, 1967):

$$d_W = \frac{W_1 - W_2}{W_2} \times BD \times d_s$$

Where, d_W is the soil moisture content on depth basis, in cm; BD is the bulk density of the soil; d_S is the depth of soil in cm; W_1 and W_2 are fresh and dry weights of soil in grams, respectively.

The water use efficiency (WUE, kg ha^{-1}mm^{-1}) was calculated as per the equation given below:

$$\text{WUE} = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Crop water use (mm)}}$$

Yield attributes and grain yield of maize and wheat were recorded at maturity. At harvesting, five plants were selected randomly from each plot to record plant height, cob length, cob girth, number of grains per cob, ear length and grains per ear. In wheat, tillers from one meter row length were counted randomly from three spots in each plot to determine tillers per meter row length. At maturity, the net plots were harvested and sundried to record total biomass yield. After threshing, cleaning and drying, the grain yield was recorded. System productivity was worked out in terms of wheat grain-equivalent yield (WEY) by taking the market price of maize and wheat grain. Cost of cultivation was calculated based on the prevailing market price of the inputs and gross returns were calculated based on the market price of the grain and straw. Statistical analysis of the data recorded from all the replications, was carried out as per the ANOVA procedures of RBD (Gomez and Gomez, 1984).

Results and Discussion

Effect on profile soil moisture

All the planting methods resulted in higher *in-situ* moisture conservation in soil profile over flat sowing at all the stages (Figure 1a & b). Among the planting methods, highest soil moisture content was observed with ridge sowing followed by conservation furrow planting method, bed planting and deep tillage. The higher soil moisture content in ridge sowing, conservation furrow and bed planting is attributed to reduced runoff and higher infiltration of rain water into soil profile compared to flat sowing. Similar results were also observed by Wakchaure *et al.,* (2015) and Jakhar *et al.,* (2017).

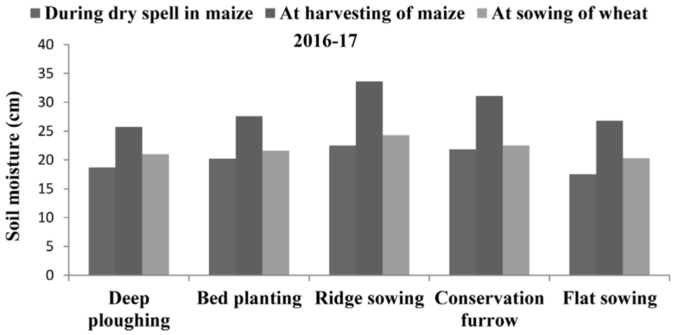

Fig. 1a: Effect of planting methods on soil profile (0-180 cm) moisture storage (2016-17)

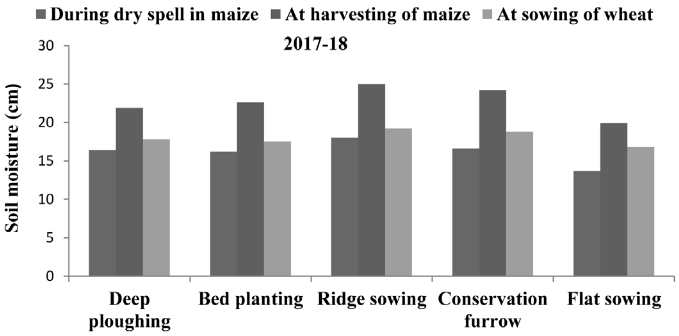

Fig. 1b: Effect of planting methods on soil profile (0-180 cm) moisture storage (2017-18)

Relative leaf water content and leaf area index

Higher relative leaf water content (Table 1) was recorded in ridge sowing of maize (75.8%) followed by conservation furrow planting method (72.8%). Lowest relative leaf water content was recorded in flat sowing (64.9%). Improvement of water status in the plant in ridge and conservation furrow planting methods was due to sufficient availability of moisture to the crop during crop growth period which led to higher water content in the leaf compared to flat sowing. Similar results were observed by Rajashekarappa *et al.,* (2014) and Mallareddy *et al.,* (2016). The *in-situ* moisture conservation by planting methods in maize significantly influenced the leaf area index. The highest leaf area index was recorded with ridge sowing followed by conservation furrow planting and lowest leaf area index was recorded under flat sowing at all the stages of crop growth (Table 1). Wheat crop sown in preceding ridge, conservation furrow, bed planting and deep ploughing sown maize plots recorded significantly higher LAI at all the stages of growth as compared to flat sowing. Increase in LAI under ridge sowing and conservation furrow method is attributed to increased availability of moisture due to reduced runoff and more infiltration of water in the furrows. Similar findings on the increase in LAI of maize and wheat due to planting methods have also been reported by Priya and Shashidhara (2016) and Salifu *et al* (2019).

Growth and yield attributes of maize and wheat

Plant height, cob length, cob girth, grains per cob and 1000 grain weight in maize crop were higher in ridge sowing, conservation furrow sowing, bed planting and deep tillage than flat sowing. The presence of sufficient moisture and good drainage conditions might have resulted in the better growth and yield attributes of maize. The soil moisture build up in soil profile resulted in healthy and vigorous growth of wheat crop and contributed to better crop stand and this effect is reflected in the higher number of tillers per meter row length, ear length, grains per ear and 1000 grain weight (Table 2). This soil moisture build-up due to *in-situ* moisture conservation helped in providing favourable environment for plant growth and responded to applied nutrients.

Table 1: Effect of maize planting methods on relative water content during dry spell in maize and leaf area index of rainfed maize and wheat (Mean data of 2 years)

Treatments	Relative water content (%)	Leaf area index					
		Maize			Wheat		
		30 DAS	60 DAS	At harvest	45 DAS	90 DAS	At harvest
Deep ploughing	68.4	1.60	4.43	3.18	1.71	2.56	1.01
Bed planting	71.2	1.65	4.55	3.41	1.83	2.64	1.06
Ridge sowing	75.8	1.74	4.88	3.58	2.01	2.88	1.22
Conservation furrow method	72.8	1.74	4.74	3.51	1.95	2.78	1.11
Flat sowing	64.9	1.55	4.23	3.09	1.67	2.46	0.92
CD (0.05)	1.48	0.11	0.29	0.24	0.13	0.18	0.10
CV (%)	4.63	6.69	6.10	6.89	6.80	6.40	8.76

Table 2: Effect of maize planting methods on yield attributes of rainfed maize and wheat (Mean data of 2 years)

Treatments	Maize					Wheat				
	Plant height (cm)	Cob length (cm)	Cob girth (cm)	No. of grains cob^{-1}	1000-grain wt. (g)	No. of tillers per meter row length	Plant height (cm)	Ear length (cm)	Grains ear^{-1}	1000-grain wt. (g)
Deep ploughing	239	14.0	12.2	354	241	73	90	10.1	47.1	39.4
Bed planting	247	14.6	12.5	364	244	77	93	10.1	47.7	40.0
Ridge sowing	263	15.8	13.0	399	255	84	98	10.8	51.1	42.1
Conservation furrow method	256	15.5	12.7	388	248	81	95	10.4	49.3	41.5
Flat sowing	232	13.6	12.1	338	232	71	88	9.5	44.5	38.9
CD (0.05)	14.1	0.90	0.51	28.0	9.34	6.26	4.68	0.53	3.56	1.63
CV (%)	5.50	5.95	3.94	7.37	3.71	7.91	4.89	5.08	7.19	3.90

Yield, water use efficiency, system productivity and economics

In maize, *in-situ* moisture conservation practices like ridge planting, conservation furrows, bed planting and deep ploughing resulted in significant increase in the yield over flat sowing with a respective increase of 18.1, 16.2, 11.6 and 7.7 per cent. Ridge planting of maize resulted in highest WUE (6.68 kg ha^{-1}mm^{-1}). The yield of succeeding wheat crop also improved due to *in-situ* moisture conservation in maize (Table 3) but significant increase occurred in ridge sowing and conservation furrow methods. Ridge sowing and conservation furrow planting increased wheat yield by 19 per cent and 15.7 per cent over flat sowing respectively and also resulted in highest water use efficiency. Chimdessa *et al.* (2019) and Okbagabir *et al.* (2017) also reported increase in yield of maize in ridge sowing moisture conservation method. The ridge sowing, conservation furrow and bed planting methods reduced runoff from the field and provided more time for water to infiltrate into the soil profile. The moisture stored in the profile is conserved for the succeeding wheat crop through tillage immediately after the harvest of maize crop by creating soil mulch (Dhaliwal *et al.,* 2013). Highest system productivity was recorded in ridge sowing (7131 kg ha^{-1}) followed by conservation furrow planting methods (6906 kg ha^{-1}) which gave additional income of Rs 24,056 and Rs. 19,656 ha^{-1} respectively than flat sowing. Thus, ridge sowing and conservation furrow method of maize planting are useful climate resilient technologies to mitigate dry spell period under rainfed conditions and these technologies improve maize and wheat production in the study area and may be useful in similar agro-ecologies by acting as moisture conservation furrows during low rainfall and as drainage channel to prevent water logging in high rainfall events.

Table 3: Effect of maize planting methods on yield, WUE and maize-wheat system productivity and economics (Mean data of 2 years)

Treatments	Grain yield (kg ha^{-1})		Straw yield (kg ha^{-1})		Water use efficiency (kg ha^{-1} mm^{-1})		System productivity (kg ha^{-1})	Net returns (Rs ha^{-1})	BC: ratio
	Maize	Wheat	Maize	Wheat	Maize	Wheat			
Deep ploughing	3627	2817	7509	4494	5.92	13.3	6164	63148	2.04
Bed planting	3786	2977	7938	4684	6.18	14.0	6471	68921	2.14
Ridge sowing	4088	3359	8522	5419	6.68	14.7	7131	82155	2.34
Conservation furrow method	3996	3217	8206	5147	6.54	14.9	6906	77755	2.28
Flat sowing	3347	2712	6919	4278	5.47	12.8	5801	58099	2.00
CD (0.05)	279	285	583	412	0.46	1.30	521	9454	0.15
CV (%)	7.2	9.15	7.23	8.32	7.19	9.01	5.1	8.85	4.33

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