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Productivity and water use of rainfed pearlmillet (*Pennisetum glaucum*) as influenced by summer ploughing and *in-situ* moisture-conservation practices under semi-arid conditions of north-west India

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ABSTRACT

A 2-year field experiment was conducted during the rainy season of 1997 and 1998 to study the effect of 3 summer ploughing (no summer ploughing, summer ploughing and summer ploughing + FYM + insecticide + herbicide) and 6 moisture-conservation practices (uniform row sowing, paired row planting, ridge-furrow, straw mulch, kaolin and straw mulch + kaolin) on the productivity and water-use efficiency of rainfed pearlmillet [*Pennisetum glaucum* (L.) R. Br. emend. Stuntz]. Summer ploughing + FYM + insecticide + herbicide gave highest grain yield (22.70 and 25.09 q/ha in 1997 and 1998 respectively), which was at par with summer ploughing alone but significantly superior to no summer ploughing. Marked variation in water-use efficiency, consumptive use and moisture-extraction pattern by pearlmillet was observed due to summer ploughing during both the years. Straw mulch + kaolin recorded highest grain yield (21.78 and 26.97 q/ha), consumptive use (266.33 and 298.72 mm) and water-use efficiency (9.46 and 9.03 kg grain/ha/mm) in 1997 and 1998, respectively, and the lowest being by uniform row sowing. Straw mulch + kaolin and straw mulch alone were at par with each other but were superior to all other treatments in terms of yield, consumptive use and water-use efficiency.

Key words : Summer ploughing, Moisture-conservation practices, Water-use efficiency, Moisture-extraction pattern, Consumptive use

Pearmillet is cultivated in areas, with the annual average rainfall ranging 150 to 700 mm. In spite of inherent drought-escaping mechanism, the crop responds well to improved agronomic management and moisture-conservation practices (Bhatnagar *et al.*, 1998). About 97 % of the area under pearlmillet is rainfed and is characterized by poor fertile soils having low moisture-holding capacity, poor infiltration rate and

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high runoff losses. Mid-season drought during growing period is one of the main causes of low yields of rainfed pearlmillet. Mid-season correction through mulches, antitranspirants, land layouts and planting methods are effective in increasing productivity and water use by pearlmillet (Lal *et al.*, 1992; Kaushik and Gautam, 1994; Kaushik and Lal, 1997). An investigation was therefore undertaken to find out suitable practices for higher productivity and *in-situ* moisture conservation under limited moisture availability.

MATERIALS AND METHODS

A field experiment was conducted at Indian Agricultural Research Institute, New Delhi, during the rainy season of 1997 and 1998. The experiment site is situated at 28° 40' N 77° 11' E longitude and at an altitude of 228.0 m above mean sea-level. It has a semi-arid and subtropical climate with hot dry summers and severe cold winters. The mean annual rainfall is about 650 mm, of which 80% is received during the monsoon period. The total rainfall received during the crop season was 337.0 mm in 1997 and 468.2 mm in 1998, which was not uniformly distributed throughout the crop season. The mean annual pan evaporation is about 850 mm. The soil was loamy sand in texture having pH 7.30 (Jackson, 1958), and electrical conductivity 0.190 dS/m (Piper, 1950). The bulk density and field capacity from each layer of the soil (0–90 cm) were measured as per the method of Piper (1950) and PWP by pressure membrane method (Richards, 1954). The Walkely and Black organic carbon content of the soil was 0.38% (Jackson, 1958), total N content 0.0392% (Jackson, 1958), Olsen P 15.25 kg/ha (Jackson, 1958), available K_2O and 270 kg/ha (Toth and Prince, 1949).

The experiment was laid out in split-plot design with 3 summer ploughing: M_1, no summer ploughing; M_2, summer ploughing alone; and M_3, summer ploughing + FYM @ 10 tonnes/ha + atrazine @ 0.5 kg a.i./ha + BHC @ 25 kg/ha) as main plot treatments and 6 moisture-conservation practices [S_1, uniform row sowing (45 cm); S_2, 30/60 paired row sowing; S_3, ridge and furrow sowing (45 cm); S_4, straw mulch @5 tonnes/ha; S_5, 6% kaolin spray; and S_6, straw mulch + kaolin spray) as subplot treatments with 3 replications. Pearlmillet hybrid 'Pusa 322' was sown on 2 July 1997 and 18 June 1998. The crop was fertilized with a uniform dose of 40 kg N, 30 kg P_2O_5 and 30 kg K_2O/ha. Half of N and full dose of P and K were drilled in seed rows at the time of sowing and the remaining half N was broadcast 25 days after sowing. Deep ploughing during summer months was done as per treatments. The FYM @ 10 tonnes/ha along with BHC @ 25 kg/ha also incorporated at the time of summer ploughing. Atrazine @ 0.50 kg a.i./ha was applied as pre-emergence. In ridge-furrow treatment crop was sown in furrows. Kaolin 6% spray was done when the drought set in, i.e. in third week of August and first week of September in 1997 and fourth week of July and second week of August in 1998.

Soil samples from 3 soil depths, i.e. 0–30, 30–60 and 60–90 cm layers were taken periodically at 25 days interval for consumptive use, water-use efficiency and moisture-depletion pattern measurement. The total consumptive use was calculated by determining the depletion of soil moisture from each layer during the entire growth period of the crop.

RESULTS AND DISCUSSION

Yield

In general, the yield was higher in 1998 than in 1997, owing to more favourable rainfall during the crop-growth period. However, the impact of summer ploughing and moisture-conservation practices was observed during both the years (Table 1). Summer ploughing practices gave significantly higher grain yield than no summer ploughing. Summer ploughing + FYM + insecticide + herbicide, though recorded maximum grain yield, it was at par with summer ploughing alone. Straw yield showed the trends almost similar to grain yield. These results confirm the findings of Browning *et al.* (1994) and Singh *et. al* (1997. Among the various moisture-conservation practices straw mulch + kaolin spray proved best treatment (Table 1), giving significantly higher grain and straw yields, followed by straw mulch alone, kaolin spray alone and paired row planting. Thus, moisture conservation during mid-season moisture- stress conditions increased the productivity of pearlmillet. Straw mulch minimized the evaporation losses and kaolin spray transpiration losses, resulting in extended periods of storage and availability of water in soil profile for crop growth (Devenport and Hagan, 1977; Kaushik and Gautam, 1994; Bhatnagar *et al.*, 1998)

Water use

Summer ploughing along with incorporation of FYM, BHC and atrazine registered higher consumptive use, rate of water use and water-use efficiency (WUE) compared with no summer ploughing but could not produce marked difference compared to summer ploughing alone (Table 2). The improved water use by the pearlmillet was registered owing to availability of moisture for longer periods (Singh *et al.*, 1997) and better root development, thereby more extraction of water from soil (Prasad and Tripathi, 1999).

Among the different *in-situ* moisture-conservation practices, the maximum consumptive use of water and daily water use by the pearlmillet was recorded in straw mulch and kaolin spray treatments and the lowest being in uniform row sowing (Table 2). The ridge-furrow and paired row planting systems, though could not produced marked influence on water use compared with each other showed marked superiority to uniform row sowing and inferiority to straw mulch and kaolin application. The improved water use by the pearlmillet in straw mulch and kaolin treatments might have attributed to more availability of water in the soil, profuse growth of the plants and more dry-matter production compared with rest of the treatments. Results in this consonance were also reported by Kaushik and Gautam (1994) and Kaushik and Lal (1997). Maximum water-use efficiency (WUE) both in terms of grain and total biomass yield was recorded under straw mulch + kaolin, followed by straw mulch alone and

Table 1. Effect of summer ploughing and moisture-conservation practices on yield of pearlmillet

Treatment	Grain yield (q/ha)		Stover yield (q/ha)		Biological yield (q/ha)		Harvest index (%)	
	1997	1998	1997	1998	1997	1998	1997	1998
Summer ploughing								
No summer ploughing	18.18	19.12	56.52	56.55	74.70	75.67	24.00	24.98
Summer ploughing	21.73	22.92	61.41	59.76	83.14	82.68	25.97	27.51
Summer plouhing + FYM + insecticide + herbicide	22.70	25.09	62.72	62.17	85.42	87.28	26.44	28.72
CD (P = 0.05)	1.90	1.55	4.72	4.39	6.29	5.23	2.45	2.52
Moisture-conservation practices								
Uniform row sowing	15.26	16.64	54.23	52.98	64.49	69.62	21.81	23.59
Paired row sowing	20.09	20.77	59.73	56.66	79.83	77.43	25.10	26.68
Ridge-furrow	17.85	21.95	56.93	59.84	74.78	81.80	23.76	26.76
Straw mulch	24.04	25.54	64.25	64.19	89.29	89.73	28.02	28.47
Kaolin spray	21.78	22.39	60.55	28.00	82.33	80.39	26.42	27.73
Straw multch + kaolin spray	25.19	26.97	65.61	65.28	90.80	92.25	27.73	29.0
CD (P = 0.05)	2.69	2.09	6.67	6.21	8.91	7.39	3.47	3.56

Table 2. Effect of summer ploughing and moisture-conservation practice on consumptive use, rate of water use and water-use efficiency of pearlmillet

Treatment	Consumptive use (mm)		Rate of water use (mm/day)		Water-use efficiency			
					Grain (kg/ha/mm)		Biomass (kg/ha/mm)	
	1997	1998	1997	1998	1997	1998	1997	1998
Summer ploughing								
No summer ploughing	247.70	277.28	3.49	3.60	7.34	7.00	30.16	27.29
Summer ploughing	258.30	288.07	3.64	3.70	8.41	7.96	32.19	28.70
Summer plouhing + FYM + insecticide + herbicide	260.07	295.11	3.66	3.88	8.73	8.50	32.85	29.58
Moisture-conservation practice								
Uniform row sowing	244.73	264.17	3.45	3.43	6.24	6.30	28.39	26.35
Paired row sowing	248.06	278.88	3.49	3.62	8.10	7.45	32.18	27.76
Ridge-furrow	252.63	289.05	3.56	3.75	7.07	7.59	29.60	28.30
Straw mulch	263.06	296.16	3.71	3.85	9.52	8.62	33.94	30.30
Kaolin spray	254.53	290.78	3.58	3.78	8.55	7.70	32.35	27.65
Straw mulch + kaolin spray	266.33	298.72	3.75	3.88	9.46	9.03	34.09	30.88

kaolin spray alone and the lowest being recorded under uniform row planting. The paired row planting and kaolin spray alone were at par with each other in terms of WUE, but inferior to straw mulch and superior to uniform row planting and ridge-furrow planting (Table 2). This improvement in water-use efficiency might be due to more availability of water for longer periods, vigorous growth of the plants and more yield (Kaushik and Lal, 1997).

Moisture-extraction pattern

In general, the depletion of soil moisture was highest from the top layer of the soil (0–30 cm) and it diminished with the increasing depths (30–90 cm) irrespective of the treatments applied. The amount of soil moisture extracted by the pearlmillet from different layers of soil varied due to summer ploughing treatments. Higher percentage of moisture depletion was registered from 0–30 cm soil layer in no summer ploughing, followed by summer ploughing alone and summer ploughing + FYM + insecticide + herbicide (Fig. 1). This might have attributed to slow infiltration and surface feeding of roots in case of no summer ploughing. However, reverse was true in case of subsequent layers, i.e. 30–60 and 60–90 cm depths, due to more infiltration of conserved moisture in lower layers of the soil. These findings confirm those of Singh *et al.* (1997).

Various *in-situ* moisture-conservation practices proved beneficial in improving the extraction of moisture from lower layers of the soil. In straw mulch and straw mulch + kaolin spray treatments less moisture was

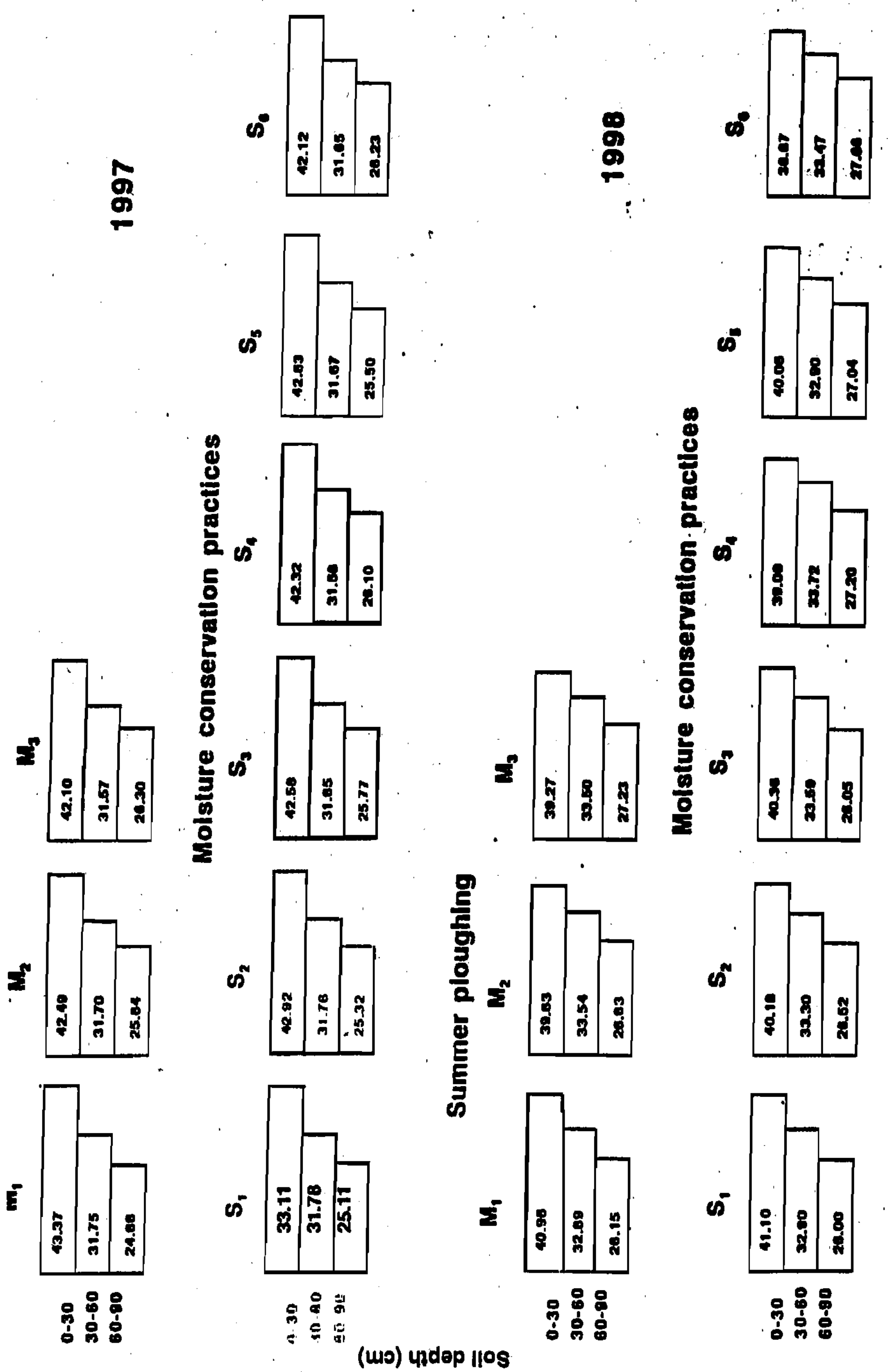

Fig. 1. Soil-moisture depletion pattern by pearlmillet as influenced by summer ploughing and moisture-conservation practice

extracted by the pearlmillet from top layer compared to all other treatments and reverse was recorded in lower layers of the soil. The other practices could not produce marked influence on extraction pattern (Fig. 1).

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