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Effect of rainwater management and crop establishment methods on growth attributes and yield of rice (*Oryza sativa* L.) in high rainfall areas of Himachal Pradesh

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Abstract

A field experiment was conducted during the rainy seasons of 2003 and 2004 at the Experimental Farm of Department of Soil Science, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur to study the effect of rainwater management and crop establishment methods on growth attributes and yield of rice (*Oryza sativa* L.) in high rainfall areas of Himachal Pradesh. Continuous submergence (R_4) proved the best and recorded significant increase in number of tillers and plant dry matter. R_4 also recorded significantly highest grain yield and it was followed by the treatment with 25 cm bund height (R_2) receiving diverted runoff from adjoining maize plots. Transplanting method gave the highest mean grain yield (25.9 and 31.5 q/ha) during 2003 and 2004. It recorded 22.2 and 61.9 per cent increase in grain yield over wet seeding and dry seeding methods during 2003 whereas during 2004 the increase in grain yield was 20.7 per cent over wet seeding and 65.8 per cent over dry seeding.

Key words: Rain water management, rice, growth attributes, yield, crop establishment methods.

Introduction

In Himachal Pradesh, rice is one of the most important cereal crops only next to wheat on area basis. The crop is cultivated from foot hill plains to an altitude of 2290 m above mean sea level, covering an area of 79.2 thousand hectares with total production of 123.5 thousand tonnes (Anonymous, 2008). Low productivity of the crop in the state is due to non-availability of assured irrigation as 81 per cent of the area is rainfed. However, the shortage of water is not caused by low rainfall, rather by a lack of capacity for sustainable management and use of available water. District Kangra, which accounts for 44 per cent of the total area under rice in the state, receives an annual rainfall of 1987 mm (mean of 20 years 1986-1997, Thakur, 1998). Bulk of this rain (about 80%) occurs during *Kharif* season between mid June (11-17) to mid Sept (10-18) due to South West monsoon. However, the prevalent land slope coupled with high intake rate of water causes the major portion of rainwater to run away from the fields as runoff, leaving insufficient quantity behind for utilization of crop plants. Suitable technologies are required to conserve this rainwater for increasing rainfall effectiveness and crop productivity. Gupta *et al.*, 2002 advocated construction of peripheral bunds of 18-20 cm height around rice fields for obtaining higher production of rice and irrigation water use efficiency. Method of crop establishment is an important non-monetary input that can help in realizing higher yields of rice. In Himachal Pradesh, rice production involves two principal methods of establishment: direct seeding and transplanting. Direct seeding includes dry and wet seeding viz. direct sowing of dry seeds and sowing of sprouted seeds in puddled soil. The three methods of rice cultivation show considerable effect in influencing growth parameters and grain yield. Hence, an experiment was planned to determine the effect of different rainwater management treatments and crop establishment methods on growth parameters and yield of rice under high rainfall areas of Himachal Pradesh.

Materials and Methods

The present field experiment was conducted at the Experimental Farm of Department of Soil Science, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur during *kharif* seasons of 2003 and 2004. The area falls in sub-mountane hill region characterized by cool winters and mild summers. The soil of the experimental site was acidic in reaction (pH 5.5) and silty clay loam in texture having a bulk density of 1.08 g/cm^3 (0-15 cm depth) and infiltration rate of 2.13 cm/hr. The

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soil was categorized as high in organic carbon (1.02 %), available phosphorus (29.0 kg/ha) and potassium (293.3 kg/ha) and medium in available nitrogen (291.6 kg/ha) in the 0-15 cm soil. There were 12 treatments consisting of four levels of rain water management and three methods of crop establishment methods laid out in split plot design and replicated thrice. The main plots (6.0 m X 8.0 m) comprised of four rainwater management treatments viz. R_1, raising rice plot bund height to 25-30 cm with no additional runoff from the maize plot; R_2, raising rice plot bund height to 25-30 cm + runoff inflow from adjoining upper maize plot of double the size of rice plot; R_3, raising rice plot bund height to 10 cm with no additional runoff from the maize plot and R_4, Continuous submergence (1-5 cm) through irrigation/rainfall with 10 cm bund height and no additional runoff inflow. The sub-plot treatments (6.0 m X 2.0 m) comprised of three crop establishment methods viz. M_1, direct seeding in unpuddled soil +Halod; M_2, direct seeding of sprouted seeds in puddled soil and M_3, transplanting. The crop was sown on 11th and 10th June (dry seeding/seed soaking/nursery raising) during 2003 and 2004, respectively. For direct seeding dry seeds @ 100 kg/ha were sown directly in the prepared seedbed in upland conditions (unpuddled soil) and was followed by halod (ploughing in standing water 30 days after sowing). In wet seeding, water soaked seeds for 36 hours@ 80 kg/ha were sown in puddled soils while transplanting was done by replanting nursery raised 30 days old seedlings in puddled soils. Nutrients through urea, single super phosphate and muriate of potash were applied @ 90 kg N, 40 kg P_2O_5 and 40 kg K_2O. Among main plot treatments, R_4 was kept continuously submerged in water (1-5 cm) either through rainfall or irrigation while in R_1, R_2 and R_3, the crop was irrigated when the soil matric potential was high (>-10kPa). A total rainfall of 1833 and 1731.3 mm was received during the crop season between June to October during 2003 and 2004, respectively. Plant height at different growth stages was recorded from five tagged plants in the net plot area while tillers from two randomly selected 40 cm X 50 cm spots were recorded and expressed on per square meter basis. To record plant dry matter, all plants from the sampling zone (40 cm X 50 cm) were harvested at ground level and oven dried. Quadrate sampling (50cm X 50cm) was used to determine the weed dry mass at harvest. Crop yield was determined by manually harvesting and threshing the produce from net plot area.

Results and Discussion

Growth parameters

The growth parameters of rice crop including plant height, number of tillers/m^2 and dry matter were significantly influenced by rainwater management treatments. R_4 recorded significantly taller plants at 90 DAS/60 DAT during 2003 and at harvest during both the years (Tables 1). Increase in the plant height in R_4 treatment could be explained due to stimulating effect of water in cell enlargement and cell elongation. It was also found that numbers of tillers in general were higher in R_4 treatment. Such increase in tillers might also be due to better moisture and nutrient availability under continuous submergence conditions. Similar results were reported by Tarafder and Khan (1999) who found that continuous flooding of rice crop significantly increased the number of tillers/hill and plant height in rice. The increased dry matter production in continuously submerged plots (R_4) compared to the other rainwater management treatments might also be due to increase in leaf area and higher photosynthate production and lesser weed competition.

The effect of crop establishment methods on plant height was significant at all growth stages, unlike rainwater management treatments. Tallest plants were found in transplanted rice (M_3) followed by sowing of sprouted seeds (M_2) and direct seeding+halod methods (M_1). Uniform plant population in M_3 because of proper plant spacing provided better growth conditions in respect of space, light and nutrients and hence taller plants. Tillers/m^2 were also significantly the highest in transplanted rice at all growth stages though only 35 kg/ha seed rate for nursery raising was used in this treatment compared to 80 and 100 kg/ha used in sprouted seeding (M_2) and direct seeding (M_1) methods. Prasad *et al.* (2001) also recorded higher tillers/m^2 in transplanted rice which also support the present findings. During both years, direct seeding + halod had least tiller density. Comparatively lesser number of tillers in the crop establishment by sowing dry seeds in dry soil (M_1) might have been due to prevailing oxidized conditions resulting in relatively low

availability of applied nutrients as reported by Dedatta (1981). Besides, the higher intensity of weeds might have increased the weed-crop competition, hence affected the growth and development of rice adversely including tillering. The dry matter production at harvest was also significantly higher in transplanted rice. Increase in dry matter production might have occurred due to favourable effect of puddling which usually decreases weed competition and increases nutrient availability, facilitates seedling establishment and increases water retention capacity of soil.

Dry matter accumulation by weeds

The field was mainly infested with species of *Ageratum conyzoides, Echinochloa colonum, Cyperus rotundus, Cyperus iria, Paspalum spp.* and *Elucine indica.* Dry weight of weeds at harvest was significantly lower in R_4 during both the years (Table 2). Significantly less weed population in R_4 might be due to favourable influence of continuous flooding as germination and emergence of many upland weeds get checked under flooded conditions (Bhagat *et al*., 1996). Among crop establishment methods, transplanted rice (M_3) recorded minimum weed dry weight during both the years of experimentation that was significantly lower to M_1 and M_2 methods during 2004.

Table 1. Growth parameters of rice influenced by rain water management and crop establishment methods

Treatment	Plant height (cm)						Dry weight (g/m^2)					
	60DAS/30DAT		90DAS/60DAT		Harvest		60DAS/30DAT		90DAS/60DAT		Harvest	
	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
Rainwater management (R)												
R_1	57.1	48.8	80.9	79.0	88.0	86.1	91.1	90.6	174.3	185.1	498.6	744.0
R_2	59.8	49.9	85.8	79.5	93.7	90.7	108.8	138.8	198.3	253.6	609.3	861.5
R_3	58.8	49.0	83.0	78.7	90.6	89.7	86.6	106.3	143.8	177.1	443.4	652.9
R_4	61.3	53.0	89.1	80.0	95.9	96.8	123.7	129.6	229.3	272.6	716.7	892.8
SEm ±	1.0	1.0	1.3	0.8	1.2	1.0	5.5	3.4	8.8	9.6	32.8	32.0
CD (P=0.05)	NS	NS	4.3	NS	4.1	3.4	19.0	11.9	30.5	33.3	113.4	110.9
Crop establishment method (M)												
M_1	57.5	48.7	77.2	77.6	87.4	84.6	73.8	86.8	140.8	176.4	438.4	641.3
M_2	62.1	50.1	91.1	77.6	94.2	93.3	120.1	126.1	206.2	231.0	626.4	789.4
M_3	58.2	51.6	85.8	82.7	94.5	94.7	113.8	136.3	212.4	258.5	636.2	932.7
SEm ±	1.1	0.7	1.5	1.4	1.4	1.3	5.3	7.0	11.5	7.8	20.0	30.4
CD (P=0.05)	3.3	2.0	4.4	4.1	4.1	3.9	15.8	21.0	34.4	23.4	60.0	91.1

Table 2. Weed dry weight in rice as influenced by rain water management and crop establishment methods

Treatments	Weed dry weight (g/m^2)		Grain yield (q/ha)		Straw yield(q/ha)	
	2003	2004	2003	2004	2003	2004
Rainwater management (R)						
R_1	59.3 (7.4)	83.9 (8.9)	18.6	21.5	34.3	55.9
R_2	50.4 (6.8)	70.5 (7.8)	22.8	26.7	40.7	66.8
R_3	85.2 (9.0)	106.4 (9.7)	15.9	18.9	30.5	48.8
R_4	36.7 (5.3)	34.3 (5.5)	26.6	35.0	45.6	79.2
SEm ±	0.47	0.64	0.6	0.8	2.1	2.4
CD (P=0.05)	1.6	2.2	2.2	2.7	7.2	8.3
Crop establishment method (M)						
M_1	101.1 (9.9)	135.0 (11.4)	16.0	19.0	30.9	48.4
M_2	38.1 (6.1)	60.2 (7.6)	21.2	26.1	37.9	63.7
M_3	34.5 (5.6)	26.2 (4.9)	25.9	31.5	44.6	75.9
SEm ±	0.4	0.4	0.6	0.6	1.6	1.7
CD (P=0.05)	1.2	1.8	1.8	1.7	4.7	5.1

Values in parentheses are means of square root transformation

Weed growth was more in the direct seeded unpuddled than in the puddled (wet seeding and transplanting methods) conditions. High percolation rates under unpuddled conditions made it difficult to maintain standing water which helps to check weed growth (Hobbs *et al.*, 2002; Rathore *et al.*, 1996).

The interaction effect between rainwater management and crop establishment methods on number of tillers was found significant at 60 DAS/30 DAT, 90 DAS/60 DAT and harvest in the second year only. During 2004 at 90 DAS/60 DAT and harvest, the maximum tiller count was observed in R_4M_3 whereas at 60 DAS/30 DAT, the maximum tiller count was recorded in R_4M_2. R_3M_1 recorded the minimum number of tillers at all the stages.

Yield parameters

Grain and straw yield

The grain yield of rice crop was generally higher in 2004 as compared to 2003 (Table 2) irrespective of rainwater management and establishment methods. This was on account of blast incidence that affected crop growth and hence recorded lower yield during 2003.

Rice grain yield under continuous submergence (R_4) was significantly higher during both the years (26.6 and 35.0 q/ha) and was followed by treatment with 25-30 cm bund height (R_2). Straw yield was also the highest in R_4 treatment. The higher grain and straw yields in R_4 treatment were due to continuous moisture availability and replenishment which probably helped in better availability and uptake of nutrients and translocation of assimilates at appropriate time that resulted in improved values of yield contributing characters and hence the yield. In R_2, the increased grain yield was due to better moisture availability because of more storage of runoff water. The results are similar to those reported by Chakor *et al.* (1983) who found that erection of 25-30 cm high bunds around rice fields stored total rainwater and increased rainwater effectiveness by increasing yields under Palampur conditions.

Table 3. Interaction effect of rainwater management and crop establishment methods on tillers/m^2 during 2004

Rainwater management (R)	Tillers (No./m^2)								
	Crop establishment methods								
	60 DAS/30DAT			90 DAS/60DAT			Harvest		
	M_1	M_2	M_3	M_1	M_2	M_3	M_1	M_2	M_3
R_1	351.7	378.3	421.7	316.7	338.3	406.7	301.7	323.3	381.7
R_2	381.7	431.7	456.7	368.3	378.3	440.0	316.7	368.3	413.3
R_3	301.7	365.0	423.3	271.7	338.3	408.3	255.0	316.7	393.3
R_4	396.7	466.7	443.3	370.0	455.0	495.0	345.0	430.0	481.7
	SEm±	CD (P=0.05)		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)	
To compare different (M) at same level of (R)	10.77	32.30		11.21	33.61		9.34	27.99	
To compare different (R) at same or different level of (M)	13.48	44.01		11.81	37.57		13.71	45.49	

Transplanting method of rice establishment gave the highest mean grain yield (25.9 and 31.5 q/ha) during 2003 and 2004, and recorded 22.2 and 61.9 per cent increase in grain yield over wet seeding (M_2) and dry seeding (M_1) methods, respectively during the first year. This increase in grain yield over wet seeding and dry seeding methods was 20.7 and 65.8 per cent during the second year. Straw yield was also found significantly higher in transplanted rice during both the years. Similar results are reported by Singh *et al.* (2001). The increase in grain and straw yield was mainly attributed to effect of puddling in better weed control and maintenance of suitable water regime.

The interaction effect in terms of grain yield between rainwater management and crop establishment methods was found significant during both the years (Fig 1a and 1b). R_4 in combination with M_3 had significantly the highest grain yield over all other treatment combinations during both the years with the exception of R_4M_2 method that remained statistically at par with R_4M_3 during the second year. M_2 recorded a significant increase in grain yield over M_1 at all treatments of rainwater management. The lowest grain yield was recorded in R_3M_1 treatment during both the years.

(A) S.Em.± (1.22) CD (P=0.05) = 3.65
(B) S.Em.± (1.18) CD (P=0.05) = 3.71

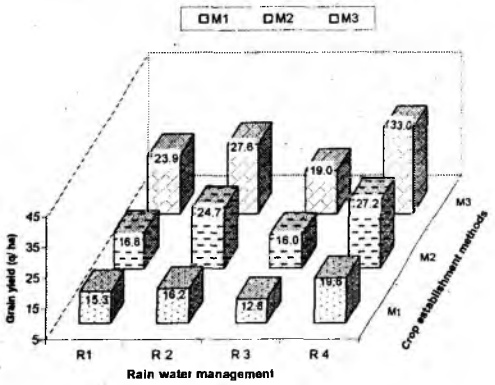


Fig. 1a. Effect of different treatments on grain yield of rice during 2003

(A) S.Em.± (1.11) CD (P=0.05) = 3.34
(B) S.Em.± (1.20) CD (P=0.05) = 3.84

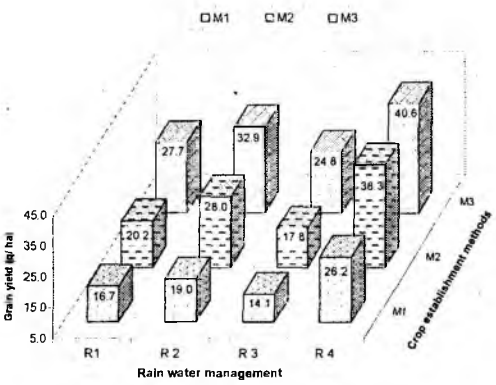


Fig. 1b. Effect of different treatments on grain yield of rice during 2004

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