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Research Paper

Yield, water use and economics of chickpea (*Cicer arietinum*) as influenced by different levels of irrigation and mulches

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ABSTRACT

A field experiment was conducted during the winter (*rabi*) season of 2010–11 and 2011–12 at Mohanpur, West Bengal, to evaluate the effect of irrigation and mulch on yield, nutrient uptake and water use of chickpea (*Cicer arietinum* L.). Chickpea irrigated at an irrigation water: cumulative pan evaporation (IW : CPE) of 0.6 showed 7.22% and 22.65% higher seed yield than that an IW : CPE of 0.4 (0.98 t/ha) and rainfed (0.85 t/ha), respectively, and was found significantly superior. The maximum seed yield of about 1.00 t/ha under the treatment receiving black polythene mulch, which was about 2.94%, 6.99% and 9.35% higher than the treatments receiving straw @ 5 t/ha, water hyacinth @ 5 t/ha and no mulch, respectively. The maximum N, P, K uptake was recorded by the crop irrigated at an IW : CPE of 0.6 and treatment receiving black polythene mulch. Water-use efficiency was the highest with rainfed treatment and treatment receiving black polythene. Treatment receiving irrigation at an IW : CPE of 0.6 recorded highest net return and benefit: cost ratio while among various mulches, black polythene maintained its superiority with highest net return and B:C ratio.

Key words : Chickpea, Economics, Irrigation, Mulch, Nutrient uptake, Yield

Pulses form an integral part of the vegetarian diet in the Indian subcontinent. Besides being a rich source of protein, they maintain soil fertility through biological nitrogen fixation. Chickpea is the most important pulse crop of India in terms of both area and production. India is the largest producer of chickpea in the world sharing 65.25 and 65.49% (FAOSTAT, 2008) of the total area (11.56 million ha) and production (8.78 million tonnes) respectively. The two major constraints affecting crop production are chronic water limitations and low availability of fertile soils. Among the various water-management practices, irrigation scheduling is the most important factor which ensures timely and adequate amount of water to the crop in best possible way for optimizing agricultural production. However, the indiscriminate use could jeopardize the availability, the efficacy of this natural resource, especially for the agriculture sector. Mulching is one such approach to increase yield of crops, raise crop successfully and economically. Mulches can be used to raise productivities of the crops trough run-off control, increased infiltration, decreased evaporation and weed control. Besides these, mulch materials from organic sources add organic matter to the soil which help to increase nutrient status of the soil. Keeping all these in view, the present study was undertaken to find out the influence of irrigation scheduling and different mulch treatments on productivity, profitability, nutrient uptake, and water-use efficiency of the crop.

MATERIALS AND METHODS

The experiment was carried out during the winter (*rabi*) seasons of 2 years 2010–11 and 2011–12 at (22°58' N and 88°3' E, 9.75 m above the mean sea-level) BCKV Farm, Mohanpur, West Bengal. The soil of the experimental field was alluvial and sandy clay loam in texture, having *p*H 7.62, organic carbon 0.64 %, total nitrogen 0.059 %, available N, P and K 250.1, 14.6 and 162.4 kg/ha respectively.

The experiment was conducted in split-plot design with 12 treatments, 3 replications and 36 plots. Three levels of irrigation were randomly allotted in 3 main plots as I_1, Rainfed; I_2, irrigation at an irrigation water : cumulative pan evaporation (IW : CPE) of 0.4 with 5 cm depth; I_3, Irrigation at an IW : CPE of 0.6 with 5 cm depth, while 4 levels of mulches were allotted randomly in 4 subplots of each main plot as M_1 (no mulch application), M_2 (water hyacinth @ 5 t/ha), M_3 (straw mulch @ 5 t/ha), M_4 (black polythene with 25 micron). Polythene was applied within

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the rows after germination of the crop and was maintained till harvesting of the crop. Nitrogen (N) @ 20 kg/ha, P_2O_5 @ 40 kg/ha and k_2O @ 40 kg/ha were applied basal through urea, single superphosphate and muriate of potash, respectively, during both the years of experiment. Before sowing, seed was inoculated with *Rhizobium* culture. After shade drying chickpea variety 'Mahamaya I' was sown at a spacing of 30 cm × 10 cm with a seed rate of 75 kg/ha on 17 November of both the years. Irrigations were applied as and when required depending on irrigation scheduling. Two irrigations were applied in plots under I_3 treatment as on 6 January, 22 February 2011 in the first year of study and 31 December 2011, 19 February 2012 in the second year under study. One-irrigation in plots under I_2 treatment (on 27 and 22 January of first and second year under study) was applied. In polythene-applied mulch irrigation was applied in crop-row zone only. Total rainfall during the crop-growth period was 10.4 and 11.1 mm in successive years of experiment. The crop was harvested at maturity, i.e. in third week of March and yield data were recorded.Total nitrogen content in plant material was determined in percentage according to modified Kjeldahl method, whereas phosphorus and potassium contents were determined colorimetrically and by flame photometer after tri-acid digestion respectively. Nutrient uptake by the crop was obtained as the product of concentration of nutrient and yield. Soil moisture was recorded by oven dry method at different depth of soils, depending on the depth at which moisture is to be estimated. The economic parameters like net returns and benefit: cost ratios were worked out by using prevailing market price of inputs and outputs.

RESULTS AND DISCUSSION

Yield components and protein content

Yield components of chickpea were significantly influenced by increasing levels of irrigation and different mulch treatment. Plants irrigated at an IW : CPE of 0.6 showed the maximum number of filled pods/plant, number of seeds/pod, 1,000-seed weight which were 30.06% and 62.65%, 3.45% and 7.78%, 1.07% and 2.31% significantly higher to the treatment receiving irrigation at an IW : CPE of 0.4 and treatment under rainfed condition, respectively (Table 1). This might be attributed to the fact that plants under unfavourable condition of plant growth as the result of low water supply led to lower uptake of water and nutrients and this might have decrease the rate of photosynthesis, lower translocation of photosynthesis from stem and leaves to sink and thus, yield and yield components were decreased. Kedar *et al.* (2008) and Shamsi *et al.* (2010) opined alike. Different mulch treatment, showed a positive response on yield components during both the years. Application of black polythene mulch showed the maximum number of filled pods/plant, number of seeds/pod, 1,000-seed weight followed by the application of straw mulch @ 5 t/ha and water hyacinth @ 5 t/ha. The no mulch resulted in the least values of abovesaid parameters. Singh *et al.* (2015) also observed increase in yield attributes of maize under mulching. Application of irrigation had a positive significant effect on protein content of the crop over no-irrigation. Irrigation applied at an IW : CPE of 0.4 recorded the highest protein content in

Table 1. Effect of irrigation and mulch on yield components, protein content and yield of chickpea at harvesting (pooled data of 2010–11 and 2011–12)

Treatment	Yield components at harvesting			Protein content (%)	Seed yield (t/ha)	Stalk yield (t/ha)	Harvest index (%)
	Filled pods/plant	Seeds/ pod	1,000-seed weight (g)				
Irrigation							
Rainfed	41.5	1.67	129.7	19.5	0.85	1.30	39.7
Irrigation at IW : CPE of 0.4	51.9	1.74	131.3	20.8	0.98	1.49	39.7
Irrigation at IW : CPE of 0.6	67.5	1.80	132.7	20.4	1.05	1.62	39.3
SEm±	0.39	0.01	0.15	0.19	0.002	0.006	0.27
CD (P=0.05)	1.19	0.02	0.46	0.56	0.007	0.019	NS
Mulch							
No mulch	40.7	1.69	129.6	19.5	0.92	1.33	40.8
Water hyacinth @ 5 t/ha	49.5	1.71	130.8	20.0	0.94	1.42	39.8
Straw mulch @ 5 t/ha	58.3	1.75	131.7	20.8	0.98	1.53	38.9
Black polythene	66.2	1.81	132.9	20.5	1.01	1.59	38.7
SEm±	0.31	0.01	0.16	0.20	0.001	0.007	0.29
CD (P=0.05)	0.94	0.03	0.59	0.62	0.005	0.020	0.86

IW: CPE, Irrigation water: cumulative pan evaporation seeds (20.75%) and was found to be the best treatment (Table 1), followed by irrigation at an IW : CPE of 0.6 with 1.77% lower seed protein content. Rinaldi *et al.* (2008) reported that irrigation increased protein content of chickpea. Chickpea mulched with straw @ 5 t/ha recorded the highest protein content and was found to be statistically at par with the treatment receiving black polythene mulch. Plants treated with black polythene mulch showed 1.66% lower protein content than that observed with straw mulch @ 5 t/ha.

Yield

Irrigation increased seed and stalk yields significantly owing to the improvement in yield attributing characters of chickpea during both the years (Table 1). Irrigation applied at an IW : CPE of 0.6 showed best performance in increasing the seed yield and stalk yield in both the years. Irrigation at an IW : CPE of 0.6 induced 7.22% and 22.65% increase in seed yield and 8.72% and 24.62% in straw yield over the application of irrigation at an IW : CPE of 0.4 and rainfed treatment respectively. Improvement of soil-moisture status in the root zone of a crop through irrigation favoured the growth and development of the plant and thus, increased the height, dry matter and yield attributing characters which induces better biological yield. Favourable influence of irrigation on these attributes significantly enhanced seed and stalk yields of chickpea over rainfed. Similar views were also given by Ray *et al.* (2010). Significant improvement in seed yield as well as in straw yield was observed with different mulch treatments during both the years and pooled data. Application of blackpolythene maintained its superiority with 2.23, 7.01, 9.36% increase in seed yield and 3.29, 11.35, 19.85% in stalk yield to straw mulch @ 5 t/ha, water hyacinth mulch @ 5 t/ha and no mulch respectively. Khan and Singh (2005) also reported increase in seed yield of chickpea with different mulch treatments through the improvement of yield attributes. Among irrigation levels, treatment receiving irrigation at an IW : CPE of 0.4 and rainfed showed the same result and among different mulch treatments, no mulch recorded the highest harvest index of 39.73% and 40.89% respectively.

Nutrient uptake

The differences in N, P and K uptake by the crop at harvesting might be attributed to significant variation in their concentration and respective yields brought about by the application of irrigation or different mulch over the control treatment. The N, P and K uptake by chickpea grain and straw significantly increased with the increase in levels of irrigation mainly owing to the increase in yield components and ultimately yield of the crop (Table 2).

Table 2. Effect of levels of irrigation and mulches on N, P, K uptake (kg/ha) of chickpea grain and straw at harvest

Treatment	Grain						Straw					
	N uptake (kg/ha)		P uptake (kg/ha)		K uptake (kg/ha)		N uptake (kg/ha)		P uptake (kg/ha)		K uptake (kg/ha)	
	2010–11	2011–12	2010–11	2011–12	2010–11	2011–12	2010–11	2011–12	2010–11	2011–12	2010–11	2011–12
Irrigation												
Rainfed	18.65	18.87	3.62	3.83	13.24	13.53	9.82	10.22	1.85	1.81	23.47	23.83
Irrigation at IW : CPE of 0.4	21.58	22.47	4.40	4.77	15.50	16.17	11.80	12.38	2.47	2.42	27.27	27.75
Irrigation at IW : CPE of 0.6	23.07	23.19	5.31	5.46	17.66	17.93	12.31	12.73	2.94	3.00	30.26	30.51
SEm±	0.172	0.082	0.193	0.128	0.030	0.029	0.168	0.043	0.032	0.021	0.027	0.026
CD (P=0.05)	0.519	0.249	0.582	0.387	0.093	0.087	0.508	0.132	0.092	0.065	0.085	0.082
Mulch												
No mulch	19.71	20.15	3.85	4.11	14.32	14.78	9.68	10.20	1.91	1.79	24.00	24.46
Water hyacinth @ 5 t/ha	20.53	21.01	4.27	4.42	15.00	15.39	10.82	11.34	2.32	2.24	26.02	26.39
Straw mulch @ 5 t/ha	21.99	22.14	4.66	4.90	15.93	16.23	12.34	12.58	2.60	2.65	28.39	28.64
Black polythene	22.15	22.74	5.00	5.31	16.62	17.10	12.41	12.96	2.84	2.97	29.59	29.96
SEm±	0.183	0.163	0.123	0.152	0.035	0.033	0.171	0.196	0.042	0.040	0.028	0.032
CD (P=0.05)	0.543	0.483	0.366	0.451	0.105	0.097	0.509	0.582	0.126	0.119	0.083	0.096

Chickpea irrigated an IW : CPE of 0.6 registered significantly higher nutrient uptake (23.07: 5.31: 17.66 N: P: K Kg/ha in grain and 12.31: 2.94: 30.26 N: P: K Kg/ha in straw) when compared to the other irrigation levels. Same trend was observed in the second year also, might be owing to availability of sufficient soil moisture that enhanced availability of nutrient to plant through high transpiration as also stated by Kumar *et al.* (2015). Abraham *et al*. (2010) opined alike. Considering different mulch treatments, black polythene mulch resulted the maximum N, P and K uptake by both grain and straw and was significantly superior to other 3 mulch treatments. Deshmukh *et al.* (2005) also reported that mulch improve the N, P and K status of the grain as well as soil.

Water use

Actually irrigation brought a considerable change in the soil-moisture status of the soil. The top layers of the soil were recharged for numbers of time with the increasing frequency of irrigation. The consumptive use of water (CUW) was the maximum with irrigation applied at an IW: CPE of 0.6, but water-use efficiency (WUE) was higher with rainfed treatment (Table 3). The maximum consumptive use of water (22.63 cm and 23.13 cm in successive years respectively) was observed when chickpea was irrigated at an IW : CPE of 0.6. Application of irrigation at an IW : CPE of 0.4 exhibited 9.59% and 6.25% less value in the first and second year, respectively, than irrigation at an IW : CPE of 0.6. The CUW progressively decreased with the reduction in frequency of irrigation and the minimum value was recorded with rainfed treatment. Patel *et al.* (2009) also reported that CUW by a crop increased significantly with an increase in levels of irrigation. Crop showed the maximum WUE (4.69 kg/ha/mm and 4.84 kg/ha/mm, in successive years respectively) owing to greater increase in seed yield than the increase in quantity of water use. Chickpea showed very slight variation in consumptive water use among various mulches. The maximum value (21.28 cm and 21.76 cm in successive years respectively) was observed with no-mulch treatment and the minimum value was recorded under the application of black polythene (Table 3). Application of mulch reduced the water use of the crop mainly by reducing soil temperature and evaporation and thus ultimately increased the water-use efficiency. The maximum water-use efficiency of the crop was computed in black polythene mulch and the minimum value when the crop was treated as no mulched.

Economics

Net return and benefit: cost ratio (BCR) increased steadily with the increase in irrigation number. The highest net returns and BCR were obtained from the crop irrigated at an IW : CPE of 0.6, mainly because of higher seed yield recorded by providing maximum number of irrigation. It was closely followed by the treatment receiving irrigation at an IW : CPE of 0.4. However, the lowest profit and BCR were obtained when the crop was grown as rainfed. Consequently, application of mulch fetched higher net returns over the control treatment. The highest

Table 3. Effect of different levels of irrigation and mulch on consumptive use of water (CUW), water-use efficiency (WUE) and economics of cultivation of chickpea

Treatment	CUW (cm)		WUE (kg/ha-mm)		Total cost of cultivation (× 10^3 ₹/ha)		Net returns (× 10^3 ₹/ha)		Benefit: cost ratio	
	2010–11	2011–12	2010–11	2011–12	2010–11	2011–12	2010–11	2011–12	2010–11	2011–12
Irrigation levels										
Rainfed	18.21	17.78	4.69	4.84	16.0	16.2	13.3	13.5	0.83	0.83
Irrigation at IW : CPE of 0.4	20.65	21.77	4.65	4.60	16.9	17.2	16.0	17.3	0.94	1.01
Irrigation at IW : CPE of 0.6	22.63	23.13	4.63	4.56	17.5	17.7	18.4	18.9	1.05	1.07
SEm±	0.26	0.19	0.17	0.19	0.04	0.06	0.22	0.26	0.06	0.03
CD (P=0.05)	0.78	0.57	0.53	0.56	0.15	0.19	0.65	0.73	0.17	0.11
Mulch treatments										
No mulch	21.28	21.76	4.27	4.28	16.4	17.1	13.8	14.6	0.84	0.86
Water hyacinth @ 5 t/ha	20.90	21.20	4.45	4.50	16.7	17.4	15.2	15.9	0.91	0.92
Straw mulch @ 5 t/h	20.31	20.63	4.80	4.76	16.9	17.6	16.5	16.8	0.98	0.96
Black polythene	19.48	19.97	5.10	5.11	17.2	17.9	17.3	18.0	1.00	1.01
SEm±	0.24	0.17	0.19	0.16	0.06	0.07	0.27	0.23	0.04	0.02
CD (P=0.05)	0.73	0.50	0.58	0.48	0.16	0.0.20	0.80	0.68	0.13	0.07

Market price of produce: Grain, ₹12.00/ kg; stalk, ₹0.10/kg

IW: CPE, Irrigation water: cumulative pan evaporation net returns and BCR were worked out with black polythene followed by application of straw mulch @ 5 t/ha and then water hyacinth mulch @ 5 t/ha (Table 3). However, the lowest net returns and BCR were obtained from rainfed chickpea and without any mulch treatment. These findings are in conformity with those of Thenua *et al*. (2010). However, cost of cultivation was worked out on the basis of actual inputs used in the experiment and net returns were calculated on the basis of prevailing market rates of chickpea and its dry stalk.

Thus, it can be inferred that crop receiving irrigation at an IW : CPE of 0.6 with 5 cm irrigation water maintained its superiority throughout the growth period of the crop in various aspects. Among various mulches, black polythene performed the best. As we know, the major constraints affecting crop production are chronic water limitations and low availability of fertile soils, therefore, to sustain the growth and productivity of chickpea both irrigation and mulch in adequate amounts are necessary.

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