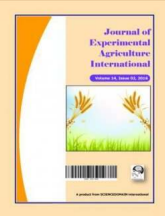

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Response of Cabbage (*Brassica oleracea* var. *capitata* L.) Cultivar "Golden Acre" to Irrigation Intervals and Different Types of Mulches

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Authors' contributions

This work was carried out in collaboration between all authors. Authors SV and AKM designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors OPG and SPS reviewed the experimental design and all drafts of the manuscript. Author BS managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted to study the effect of irrigation intervals and mulches on growth and yield of cabbage (*Brassica oleracea* var. *capitata* L.)" during Rabi season of 2015-16 at Horticulture Farm, S.K.N. College of Agriculture, Jobner. The experiment consisted of sixteen treatment combinations with four irrigation intervals (6, 9, 12 and 15 days) and four types of mulches (control, white polythene, black polythene and mustard straw) in randomized block design with three replications. The results of study clearly indicated that application of irrigation at 9 days interval as well as black polythene mulch significantly increased the growth parameters like (plant height, number of leaves, plant spread, leaf area and total chlorophyll content in leaves) and yield (head yield/plot, head yield/hectare) of cabbage. The interaction effect between irrigation at 9 days interval along with black polythene mulch was found statically at par to application of irrigation at 12 days interval along with mustard straw mulch with respect to head yield kg/plot (11.33 kg/plot) and yield q/ha (349.63 q/ha).

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Keywords: Growth attributes; yield, irrigation intervals; mulches; cabbage.

1. INTRODUCTION

Cabbage (*Brassica oleracea* var. *capitata* L.) is by far the most important member of the genus *Brassica* grown in the world. It is a crop of both tropical and temperate region. However, the major cabbage growing states are Orissa, West Bengal, U.P., Bihar, Karnataka, Maharashtra, Gujrat, Punjab and Himachal Pradesh [1]. The area under cabbage cultivation in India is 401 thousand ha with an annual production of about 9086 thousand tonnes [2]. In Rajasthan, it is mainly grown in Jaipur, Ajmer, Alwar, Sriganganagar, Tonk, Sikar, Jodhpur, Bundi, Bharatpur, Nagaur and Rajsamand. Cabbage is rich in minerals and Vitamins. It contains, Vitamin-A (2000 IU), thiamine (0.06 mg), riboflavin (0.03 mg) and vitamin-C (124 mg) per 100 g edible part. It also contains minerals like potassium, phosphorus, calcium, sodium and iron [1]. Cabbage is used as salad, boiled, cooked, dehydration and pickling purposes. It neutralizes acidity, improves digestion and appetite [3].

Mulching plays an important role in maximizing yield potentials of the crop in the arid and semi-arid regions as it may be proved beneficial by reducing water losses. Mulching has been advocated as an effective means for conserving soil moisture inside the soil. It works as an insulating material against heat or cold and also as a surface barrier to check evaporation from soil surface. Mulches can be differentiated in to organic and inorganic mulches. Organic mulches include pine bark, bark chips, compost, leaf mould, lawn clippings, pea straw, stable straw, spoiled lucerne, seaweed, mushroom compost, hay, feathers, eucalyptus mulch, manures, papers and others. However, Inorganic mulches include: gravel, scoria, crushed rock and synthetic plastics of various colours [4].

Black polyethylene mulch is used most widely because it effectively decreases or eliminates most weed growth by inhibiting photosynthesis. The use of black polyethylene mulch increases yield and earliness of vegetables in the spring [5]. Black polyethylene is popular for cool seasons because it warms the soil by contact [6]. Mulches were found to act as a barrier to the action of rainfall that compacts soil and inhibits root growth. Black plastic significantly enhanced root growth and facilitated higher nutrient uptake, thereby promoting plant growth and development [7].

Besides Mulching, Irrigation also plays an important role in maximizing yield potentials of crop. Water is one of the most important factors in successful crop production. It makes up by weight, the major portion of vegetables (about 75 per cent or more) and regulates growth and development in the plants. It is essential for photosynthesis as solvent, act as carrier of nutrients and maintains turgidity of living cells. It is also a constituent of protoplasm reagent in many important physiological processes including photosynthesis and hydrolytic processes such as hydrolysis of starch to sugar and promotes activity of soil micro-organisms. Efficient utilization of available water is therefore, necessary to ensure maximum crop production. Water economy in crop production is of special importance in Indian agriculture and particularly in Rajasthan state where nearly 624 thousand ha out of 2220 thousand ha of cultivated area is under irrigation. Appropriate Irrigation interval is to increase irrigation efficiencies by applying the amount of water needed to replenish the soil moisture to desire level, saves water resources and energy. Therefore, it is important to irrigate the crop at right stage under prevailing climatic conditions in order to utilize scare water resources effectively for crop production. Surface irrigation such as furrow, check basin and border are the most common methods in India.

2. MATERIALS AND METHODS

A field experiment was conducted at the Horticulture Farm, S.K.N. College of Agriculture, Jobner, Rajasthan during *Rabi* season 2015-16. The climate of Jobner is typically semi-arid characterized by extremes of temperature both in summer and winter, low rainfall and moderate relative humidity. The crop was transplanted on 07/11/2015 and harvested as last picking on 20/02/2016. The maximum and minimum temperature during the growing season of cabbage fluctuated 35 and 2℃, respectively. The relative humidity ranged from 52 to 70 per cent. While, the mean value of evaporation from USWB class pan ranged from 2.0 to 5.3 mm. Total rainfall received during the experimentation was 22.4 mm. The soil of experimental site was loamy sand in texture, slightly alkaline in reaction, poor in organic carbon with low available nitrogen, phosphorus & sulphur and medium in potassium content. Water of this area is partially saline in nature. The pH and EC of water were 8.1 and 1.9 d/Sm, respectively. The

pH of water is measured by using pH meter as per method of USDA Hand Book No. 60 and ECe of water is measured with the help of "Solubridge" as per method 4, USDA Hand Book No. 60 [8].

2.1 Measuring Apparatus

EC and pH meter, meter scale, leaf area meter, spectrophotometer and electronic balance.

2.2 Observations to be Recorded

In order to evaluate, five plants were randomly selected and tagged from each plot and necessary periodical observations were recorded (Table 1).

2.3 Total Chlorophyll Content in Leaves (mg/g)

The amount of total chlorophyll in leaves (mg/g) was calculated as advocated by [9].

Total chlorophyll (mg/g) = {20.5 (A645) + 8.02 (A663)} X V / {1000 X W}

Where,

A= Absorbance specific wave lengths
V= Final volume of chlorophyll extract in 80% acetone solution
W= Fresh weight of leaf sample

2.4 Treatment Details and Methods of Application

The experiment was laid out in Randomized block design with comprised of 16 treatment combinations viz. four irrigation intervals (6, 9, 12, and 15 days) and four different mulches (control, white polythene, black polythene and mustard straw). The treatments were randomly allocated to different plots using random table of [10]. The crop was irrigated immediately after transplanting. Further, irrigation was given twice at an interval of 2-3 days upto the establishment of seedlings. Thereafter, irrigation was applied as per treatment (6, 9, 12 and 15 days intervals) through check basin method. FYM procured from college dairy farm was applied in the experimental field @ 300 q/ha as basal and thoroughly mixed in the soil. A uniform dose of manures and fertilizers were also applied manually at the time of field preparation. Both the white & black polythehes of 200 gauge and mustard straw were put into bed size 1.8 × 1.8 m and the holes of 0.0254 × 0.0254 m were made on polythene sheets as per the plant and row to row distance. These prepared polythene sheets and mustard straw @ 5 t/ha including 1 cm thickness as mulch on top soil of the beds were spread over the randomly selected beds and thereafter, transplanting was done. About five weeks old seedlings of cabbage were transplanted in the field on 14th November, 2015, when average height of seedlings was about 10 cm. and between row to row and plant to plant distance was kept 45 cm × 45 cm. The root portion along with leaves attached to the head was cut with the help of sharp sickle and observations of tagged plants were recorded. The process of harvesting was started from first week of February 2016 to third week of February 2016.

2.5 Statistical Analysis

To test the significance of variation in data obtained from various growth and yield characters, the technique of analysis of variance was adopted as suggested by [11] for randomized block design. Significance of difference in the treatment effect was tested through 'F' test at 5 per cent level of significance and CD (critical difference) was worked out, wherever the results found significant.

3. RESULTS AND DISCUSSION

3.1 Effect of Irrigation Intervals on Growth Attributing Characters

The analysis of data indicated that irrigation intervals and mulches significantly affected the growth parameters (Table 2) of cabbage at different stages of crop growth. Application of irrigation at 9 days interval (I_2) recorded the maximum plant height (22.31 cm), number of leaves per plant (19.12) and average leaf area (280.48 cm^2) at 45 DAT (days after transplanting) while minimum were recorded under I_4 (15 days interval) and proved superior over 6 days (I_1) and 15 days (I_4) irrigation interval with 18.99 and 45.82 per cent higher plant height, 11.87 and 27.28 per cent more number of leaves per plant and 16.80 and 30.18 per cent higher average leaf area respectively. Application of 12 days (I_3) irrigation interval was found to be statistically at par with application of 9 days (I_2) irrigation interval.

Table 1. Methods used for estimation of different parameters/ characteristics

S. no.	Observations	Characteristics	Method followed and reference
1.	pH	pH meter	Using pH meter as per method of USDA Hand Book No. 60 [8].
2.	EC (dS/m)	EC meter	ECe of soil/water was measured with the help of "Solubridge" as per method 4, USDA Hand Book No. 60 [8].
3.	Plant spread (cm^2)	Meter scale	Spread of plant was recorded in both East–West and North-South directions, with the help of meter scale for five tagged plants at 50 days after transplanting and average spread was measured as cm^2.
4.	Leaf area (cm^2)	leaf area meter	The five tagged plants were also used for leaf area measurement. Leaf area of individual tagged plant was recorded from each plot at 45 days after transplanting by leaf area meter (LICOR-3100, Lincoln, USA) and average leaf area in cm^2 was recorded as mean value.
5.	Yield	Electronic balance	The head weight of tagged plants was taken after removing stem and leaves from each plot with the help of electronic balance and average weight of head in kg per plant was calculated and converted in yield (kg/plot and yield q/ha).
6.	Total chlorophyll content in leaves (mg/g)	Spectrophotometer	Total chlorophyll content in leaves was determined at 50 days after transplanting by using the method of [12] with slight modification. 50 mg fresh leaf material from randomly selected leaf was used for chlorophyll estimation. The material was taken in test tube to which 5.0 ml DMSO was added. These tubes were tightly capped and placed in an oven at 60℃ for 6 hrs. Finally the tubes were thoroughly shaken and extracted solvent was decantated to read at 645 and 663 nm by spectrophotometer (Systronics, India).

This pattern of results, obtained reflect that the negative trend of increasing the irrigation intervals from I_1 to I_4 level that is 6 days to 15 day interval, in no mulch plot was safely and almost completely counteracted by the placement of white and black polythene and mustard straw mulch in their respective irrigation plots. But this negative trend could not be completely counteracted by the presence of mulches in I4 level of irrigation *i.e.* 15 days of interval. Similar results were obtained by [13] who reported that the growth of cabbage increased with increasing irrigation rates. Growth of plant depends on cell expansion and enlargement which is probably most sensitive physiological aspect of a plant to water deficit leading to reducing plant productivity [14] and ultimately affect plant height. Phenolic compounds produced in plants during water stress also respond to reduce plant growth [15,16,17].

Plant spread had significant effect on different irrigation intervals and mulches at 50 days after transplanting of cabbage crop (Table 2). The maximum plant spread (2660.05 cm^2) and total chlorophyll content (0.764 mg/g) in leaves were observed with treatment I_2 (9 days irrigation interval) at 50 days after transplanting. This treatment was found to be significantly superior over rest of the treatments with an increase in plant spread as 17.67 and 37.28 per cent and 10.8 and 36.68 per cent as chlorophyll content in leaves (mg/g) over treatment I_1 (6 days) and I_4 (15 days irrigation interval), respectively.

Whereas, it was found statistically at par to treatment I_3 (12 days interval). In case of plants it might be due to that number of irrigations improved photosynthetic efficiency. Which could be attributed to the developed canopy with the increase of irrigation level [18,19]. Frequent watering to the soil especially during the early growth stages of the crop prevented water stress and kept the soil in available moisture condition that help to improve plant growth and the increased curd yield [20]. Xylem water potential varied with water supply and therefore, it may be quite effective to monitor moisture stress in plants [21]. Increasing the soil water stress decreases leaf water potential. The obtained results are in good harmony with those of [22] who found that increasing of irrigation frequency caused an increase in number of leaves of eggplant.

3.2 Effect of Mulches on Growth Attributing Characters

The data regarding the effect of different mulches on the Growth characters of cabbage has been also presented. The perusal of data in the same Table revealed that the plant height, number of leaves per plant and average leaf area at 45 days after transplanting was significantly affected by various mulches. The maximum plant height (22.64 cm), number of leaves per plant (19.45) and average leaf area (278.95 cm^2) of cabbage at 45 days after transplanting was recorded with application of black polythene (M_2) which was significantly superior than rest of the treatments but treatment M_1 (white polythene) and M_3 (mustard straw mulch) were found statistically at par to it. The increase in average leaf area was registered at the tune of 28.61 per cent under treatment M_2 over control at 45 days after transplanting. It might be due to that black polythene mulch significantly enhanced root growth and facilitated higher nutrient uptake, thereby promoting plant growth and development [7]. Mulches were also found to act as a barrier for weed growth. [18] and [19] also observed the similar results of mulching. [23] also reported that low water availability adversely affects the hormonal balance in development of plant and assimilate translocation.

Similarly, application of different mulches also significantly influenced plant spread and total chlorophyll content in leaves over control, M_1 (white polythene) and M_3 (mustard straw mulch) of cabbage. The maximum plant spread (2701.42 cm^2) and chlorophyll content (0.773 mg/g) was recorded with treatment M_2 (black polythene), being significantly superior over rest of the treatments. The increase in plant spread was recorded at the tune of 35.27 per cent over control and 38.03 and 10.58 and 6.77 per cent higher chlorophyll content in leaves over control, M_1 (white polythene) and M_3 (mustard straw) at 50 days after transplanting, respectively. It is known that the moisture conserving effect of straw mulch increases with the amount applied. [24] stated that an amount of 3000 pounds of mulch per acre (3.4 t/ha) is about the smallest rate that is effective to minimize the evaporation rate. Therefore, the relatively small amounts of straw applied would not be expected to be effective in conserving soil moisture [25]. The reason for soil moisture retained by white plastic mulch to be lower than soil moisture retained by mustard straw mulch might be due to that White plastic mulch allowed less amounts of water into the soil. However, mustard straw allowed more water thus being able to retain more water in the soil [26].

3.3 Effect of Irrigation Intervals on Yield

The data presented in Table 2 revealed that application of different irrigation intervals significantly increased head yield of cabbage. The maximum and significantly higher head yield of 10.87 kg/plot and head yield (335.56 q/ha) were obtained with the irrigation at 9 days interval (I_2) followed by treatment I_3 (12 days interval). However, it was noticed as minimum head yield of 8.07 kg/plot and 249.01 q/ha were registered under I_4 (15 days interval). The increase in head yield kg/plot and q/ha of cabbage under I_2 was recorded as 34.7 per cent and 34.76 per cent higher over treatment I_4. The increase in yield and yield attributes obtained with irrigation intervals might be due to increased photosynthesis favoured by improved photosynthesis effect as well as source to sink relationship [27]. The significant improvement in the mustard seed yield might be due to the cumulative effect of significant improvement in the value of yield attributes like number of siliqua per plant, number of seeds/siliqua and test weight [28]. [29,30,31] reported an increase in seed yield of mustard due to irrigation.

Table 2. Effect of irrigation intervals and mulches on growth attributes and yield of cabbage

Treatments	Plant height (cm)	Number of leaves per plant	Plant spread (cm^2)	Leaf area (cm^2)	Chlorophyll content in leaves (mg/g)	Yield kg/plot	Yield q/ha
Irrigation intervals							
I_1 (6 days)	18.75	16.85	2260.65	240.12	0.689	9.03	278.77
I_2 (9 days)	22.31	19.12	2660.05	280.48	0.764	10.87	335.56
I_3 (12 days)	21.56	18.27	2517.56	272.31	0.745	10.07	310.86
I_4 (15 days)	15.30	13.81	1937.63	215.45	0.559	8.07	249.01
SEm±	0.49	0.47	72.35	4.56	0.014	0.14	4.14
CD (P=0.05)	1.41	1.36	208.94	13.17	0.042	0.40	11.94
Mulches							
M_0 (Control)	15.77	13.62	1997.08	216.84	0.560	8.54	263.46
M_1 (White polythene)	19.13	17.23	2277.87	249.11	0.699	9.42	290.62
M_2 (Black polythene)	22.64	19.45	2701.42	278.95	0.773	10.44	322.10
M_3 (Mustard straw)	20.38	17.74	2399.53	263.46	0.724	9.66	298.02
SEm±	0.49	0.47	72.35	4.56	0.014	0.14	4.14
CD (P=0.05)	1.41	1.36	208.94	13.17	0.042	0.40	11.94

Table 3. Interactive effect of irrigation intervals and mulches on head yield of cabbage

Mulches levels	Irrigation intervals							
	Head yield (kg/plot)				Head yield (q/ha)			
Treatments	**I_1**	**I_2**	**I_3**	**I_4**	**I_1**	**I_2**	**I_3**	**I_4**
M_0	7.98	10.26	8.74	7.17	246.42	316.54	269.63	221.23
M_1	8.85	10.83	10.02	7.97	273.09	334.32	309.14	245.93
M_2	10.70	11.33	10.91	8.80	330.37	349.63	336.79	271.60
M_3	8.59	11.07	10.62	8.34	265.19	341.73	327.90	257.28
SEm±				0.28				8.27
CD (P=0.05)				**0.80**				**23.88**

3.4 Effect of Mulches on Yield

Data (Table 2) further indicated that use of different mulches also had significant effect on head yield of cabbage. Use of black polythene mulch (M_2) observed to be the most superior treatment to head yield (10.44 kg/plot and 322.10 q/ha) over rest of treatments and registered 22.25, 10.82 and 8.07 per cent more head yield kg/plot and 22.26, 13.12 and 10.31 per cent more yield q/ha of cabbage over control, white polythene (M_1) and mustard straw (M_3), respectively. [32] also reported the increase in curd yield of cauliflower due to black polythene mulching might occur from better moisture utilization by fall of temperature during winter checking evaporation loss and lesser competition of weeds. Similar results were also reported by [33,34] in cabbage and khol rabi, respectively. Plants under polyethylene mulch (silver on black) produced larger fruit and have higher fruit yield/plant because of better plant growth due to favourable hydro-thermal regime of soil complete weed free environment [35]. These results were in consonance with those of [36,37].

3.5 Interaction Effect on Head Yield

Interactive effect of different irrigation intervals with mulches was found to be significant on head yield/plot and head yield/ha (Table 3). The combined application of irrigation at 9 days interval + black polythene mulch (I_2M_2) proved significantly higher over rest of treatment combinations except treatment combinations I_2M_3, I_3M_2, I_2M_1, I_1M_2 and I_3M_3 which were found statistically at par to it. This treatment combination (I_2M_2) registered 58.02 per cent higher head yield kg/plot and treatment combinations I_2M_2, I_2M_3, I_3M_2, I_2M_1, I_1M_2 and I_3M_3 registered 58.04, 54.46, 52.24, 51.12, 49.33 and 48.22 per cent higher yield quintal per hectare than I_4M_0 (15 days irrigation interval without mulch), respectively. The significant increase in yield under the application of irrigation intervals and mulches was largely a function of improved growth and subsequent increase in average weight of head (kg/plant), head yield (kg/plot), head yield (q/ha) and other yield attributes as described above. The interactive advantages of combined application of irrigation intervals and mulches generally proved superior to the use of each component separately.

4. CONCLUSION

On the basis of results obtained in the treatment I_2M_0 *i.e.* Irrigation at 9 days interval without mulch and in the treatment I_2M_3 *i.e.* Irrigation at 9 days interval along with application of mustard straw mulch @ 5 t/ha) in the present experiment, it can be concluded that cabbage crop should be applied irrigation at 9 days interval either with the application of mustard straw mulch or without any kind of mulch for best results as in both the cases the results obtained are statically at par and without any significant difference from each other. Here, it is very important and pertinent to mention that though the application of mustard straw mulch initially may seem to unnecessarily increase the material as well as labour cost over it alternate *i.e.* without the application of mulch but at the same time the use of mustard straw mulch has the added advantages of increasing or maintaining the soil fertility due to its biodegradable nature (quality) and thus it produce a residual positive effects which is beneficial for the next upcoming crop on the same farm land.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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