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Suresh Kumar Meena
M.Sc. Scholar, Department of Horticulture, College of Agriculture, SKRAU-Bikaner, Rajasthan, India

Raja Ram Bunker
Ph.D. Research Scholar, Department of Horticulture, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology-Udaipur, Rajasthan, India

PK Yadav
Professor, Department of Horticulture, College of Agriculture, SKRAU-Bikaner, Rajasthan, India

Poonam
Ph.D. Research Scholar, Department of Horticulture, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology-Udaipur, Rajasthan, India

Ram Lakhan Meena
Ph.D. Research Scholar, Department of Horticulture, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology-Udaipur, Rajasthan, India

Ashok Kumar Meena
Ph.D. Research Scholar, Department of Horticulture, College of Agriculture, SKRAU-Bikaner, Rajasthan, India

Corresponding Author:
Suresh Kumar Meena
M.Sc. Scholar, Department of Horticulture, College of Agriculture, SKRAU-Bikaner, Rajasthan, India

Evaluation of irrigation levels and mulch on yield, water use efficiency and economics of cabbage (*Brassica oleracea* var. *capitata* L.) under Drip irrigation

Suresh Kumar Meena, Raja Ram Bunker, PK Yadav, Poonam, Ram Lakhan Meena and Ashok Kumar Meena

Abstract
A field experiment was conducted at Instructional Farm, Swami Keshwanand Rajasthan Agricultural University, Bikaner during *Rabi*, 2018-19 with treatment comprised of 4 irrigation levels *viz.*, 40, 60, 80 and 100% PE in the main plot and three mulch *viz.*, without mulch, straw mulch and plastic mulch in the sub plot. The experiment was laid out in split plot design and replicated thrice. Research results indicated that *viz.*, minimum days to head initiation (40.8 days), days to marketable head production (71.0 days) and maximum diameter of head (12.95 cm), average weight of marketable head (448.40 g plant^{-1}), yield (298.93 q ha^{-1}), net returns (Rs. 144342 ha^{-1}) and B:C ratio (3.30) were also observed with treatment 100% PE. Further, 80% PE gave at par values for all these parameters with 100% PE. The water use efficiency (8.05 q ha^{-1} cm^{-1}) was found maximum with 80% PE. Among various mulch minimum days to head initiation (41.2 days), days to marketable head production (72.6 days) and maximum diameter of head (11.86 cm), average weight of marketable head (385.22 g plant^{-1}), yield (256.81 q ha^{-1}), water use efficiency (8.34 q ha^{-1} cm^{-1}), net returns (Rs. 114051 ha^{-1}) and B:C ratio (2.73) were recorded under plastic mulch.

Keywords: Yield, water use efficiency, economics, irrigation levels, mulch

Introduction
Cabbage (*Brassica oleracea* var. *capitate* L.) is an important member of cole crops and belongs to family Cruciferae. It is a biennial crop of temperate region. However, it's cultivation is equally successful in the tropical and sub-tropical regions. It is grown round the year in one or the other parts of the country but mainly grown in cool season. Cabbage is rich in minerals and vitamins. It contains vitamin-A (2000 IU), thiamine (0.06 mg) and riboflavin (0.03 mg). It also contains minerals like potassium, phosphorus, calcium, sodium and iron (Fageria *et al*. 2003) [2]. Cabbage is used as salad, boiled, cooked, dehydration and pickling purposes. It neutralizes acidity, improves digestion and appetite.

A drip-irrigation system when properly designed, maintained and operated can be a production asset for a small farm. Drip irrigation is an ideal way to produce high value crops as it reduces water use, increases crop yield and gives good quality produce within less time and money as compared to traditional ways of cultivating and irrigating commercial crops. In drip irrigation, water is applied to the plant root zone with minimum losses, maintaining steady moisture in the soil profile. Its field application efficiency can be as high as 90% compared to 60–80% for sprinkler and 50–60% for surface irrigation. It is an advanced method of irrigation which helps to achieve considerable amount of water saving with high water use efficiency compared to surface irrigation method, where irrigation efficiency is low due to losses in water distribution on the field.

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 in the soil. It works as an insulating material against heat or cold and also as a surface barrier to check evaporation from soil surface. Mulching is an effective method in manipulating crop growing environment to increase yield and improve product quality by controlling weeds, ameliorating soil temperature, conserving soil moisture, reducing soil erosion, improving soil structure and enhancing organic matter content.

Materials and Methods

A field experiment was conducted at Instructional Farm, College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner during *Rabi*, 2018-19. Bikaner falls under arid ecosystem (Hot Arid Eco-region with desert and saline soils) having hot and arid climate with precipitation less than 300 mm and is characterized by deep, sandy soils with low water holding capacity. The mean maximum temperature around 48 °C during summer and minimum temperature of around 0 °C in winter were recorded in this region. The experiment was laid out in split plot design and replicated thrice. The treatment comprised of 4 irrigation levels *viz.*, 40, 60, 80 and 100% PE in the main plot and three mulch *viz.*, without mulch, straw mulch and plastic mulch in the sub plot. For irrigation through drip, first irrigation (25 mm) was given immediately after sowing and subsequent irrigations were scheduled in alternate days as per treatment.

Four weeks old seedlings of cabbage variety "Golden Acre" were planted at a distance 50 cm x 30 cm between rows and plants in last week of October. All the recommended packages of practices were followed. After transplanting, straw mulch was placed in the experimental plots @ 5 tonnes ha^{-1}, plastic mulch (25 micron) was placed between the rows. The drip lines (LLDP) were laid out at 100 cm distance and pressure compensating inbuilt dripper (4 lph). Two seedlings were planted at one dripper. Data were recorded on yield, water use efficiency and economics as per standard methods. All the data generated were subjected to analysis of variance (ANOVA) and critical difference (CD) at 5% probability level.

Result and Discussion

Effect of Irrigation levels and mulching yield, water use efficiency and economics of cabbage

The results presented in (Table 1) that irrigation levels had significant effect on yield, water use efficiency and economics of cabbage. Irrigation level of 100% PE were recorded the minimum *viz.*, (40.8 days) days to head initiation, days to marketable head production (71.0 days) and maximum diameter of head (12.95 cm), average weight of marketable head (448.40 g $plant^{-1}$),yield (298.93 q ha^{-1}),net return (Rs. 144342 ha^{-1}) and B:C ratio (3.30), which were statistically at par with treatment 80% PE (41.4 days,72.3 days,12.64 cm, 419.77 g $plant^{-1}$,279.84 q ha^{-1}, Rs. 131775 ha^{-1} and 3.07, respectively). However, irrigation level of 80% PE was recorded the maximum water use efficiency (8.05 q ha^{-1} cm^{-1}) as compared to 100% PE (7.00 q ha^{-1} cm^{-1}).This may be due to the fact that 100% PE irrigation level of drip restrain excessive vegetative growth of cabbage and enhanced head initiation and marketable head production due to more availability of sunlight and optimum availability of water Jadhav *et al.* (1990) [3]. The increase in yield and yield attributes obtained with irrigation levels might be due to increased photosynthesis favoured by improved photosynthesis effect as well as source to sink relationship. Increased water use efficiency might be due to reduced water losses through the soil, controlled deep percolation loss, elimination of runoff and irrigation to smaller portion of soil volume and more efficient plant use coupled with higher productivity under drip system Mandal and Saren (2012) [7]. Similar findings were also reported by Khodke and Patil (2012) [6], Kapoor *et al.* (2014) [5] and Kamble *et al.* (2018) [4].

The results showed in (Table 1) that mulch had significant effect on yield, water use efficiency and economics of cabbage. The minimum *viz.*, days to head initiation (41.2 days), days to marketable head production (72.6 days) and maximum diameter of head (11.86 cm), average weight of marketable head (385.22 g $plant^{-1}$), yield (256.81 q ha^{-1}), water use efficiency (8.34q ha^{-1} cm^{-1}), net return (Rs. 114051 ha^{-1}) and B:C ratio (2.73) were recorded under plastic mulch followed by treatment straw mulch. Plants under plastic mulch produced larger fruit and have higher fruit yield per plant because of better plant growth due to favourable hydro-thermal regime of soil complete weed free environment Parmar *et al.* (2013) [8]. It might be due to the fact that plastic mulch recorded highest yield of cabbage which in turn resulted in higher water use efficiency. Similar findings were also reported by Salim *et al.* (2008) [9] and Biswas *et al.* (2015) [1].

Table 1: Effect of irrigation levels and mulch on yield, water use efficiency and economics of cabbage

Treatments	Days to head initiation	Days to marketable head production	Diameter of head (cm)	Average weight of marketable head (g $plant^{-1}$)	Yield (q ha^{-1})	Water use (mm)	Water use efficiency (q ha^{-1} cm^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
Irrigation levels									
40% PE	45.1	78.0	8.50	195.20	130.14	188.50	6.90	28570	1.46
60% PE	42.6	74.0	11.00	317.77	211.84	268.00	7.90	84970	2.34
80% PE	41.4	72.3	12.64	419.77	279.84	347.50	8.05	131775	3.07
100% PE	40.8	71.0	12.95	448.40	298.93	427.00	7.00	144342	3.30
S.Em+	0.27	0.39	0.27	11.95	7.97	-	0.21	5578	0.09
CD (P=0.05)	0.94	1.35	0.94	41.36	27.58	-	0.72	19302	0.33
Mulch									
Without mulch	43.5	75.5	10.61	300.72	200.48	307.75	6.51	83620	2.46
Straw mulch	42.8	73.5	11.35	349.91	233.27	307.75	7.57	94572	2.43
Plastic mulch	41.2	72.6	11.86	385.22	256.81	307.75	8.34	114051	2.73
S.Em+	0.17	0.28	0.10	7.57	5.05	-	0.13	3533	0.06
CD (P=0.05)	0.52	0.85	0.30	22.70	15.13	-	0.40	10593	0.19

Table 2: Interaction effect of irrigation levels and mulch on diameter of head and average weight of marketable head

	Diameter of head (cm)				Average weight of marketable head (g plant^{-1})			
Treatments	**40% PE**	**60% PE**	**80% PE**	**100% PE**	**40% PE**	**60% PE**	**80% PE**	**100% PE**
Without mulch	8.06	10.57	12.17	11.64	163.33	279.33	396.33	363.90
Straw mulch	8.50	10.96	12.63	13.33	187.27	326.95	405.29	480.12
Plastic mulch	8.93	11.49	13.11	13.90	235.01	347.01	457.68	501.18
SEm±	CD (P=0.05)				SEm±	CD (P=0.05)		
M at I	0.19	0.59			**M at I**	15.14		45.39
I at M	0.31	1.06			**I at M**	17.1951.56		

Table 3: Interaction effect of irrigation levels and mulch on yield and water use efficiency

	Yield (q ha^{-1})				Water use efficiency (q ha^{-1} cm^{-1})			
Treatments	**40% PE**	**60% PE**	**80% PE**	**100% PE**	**40% PE**	**60% PE**	**80% PE**	**100% PE**
Without mulch	108.89	186.22	264.22	242.60	5.69	6.95	7.60	5.68
Straw mulch	124.84	217.97	270.19	320.08	6.62	8.13	7.78	7.50
Plastic mulch	156.67	231.34	305.12	334.12	8.39	8.63	8.78	7.82
SEm±	CD (P=0.05)				SEm±	CD (P=0.05)		
M at I	10.10	30.27			**M at I**	0.27		0.81
I at M	11.46	34.38			**I at M**	0.301.01		

Table 4: Interaction effect of irrigation levels and mulch on net returns and B:C ratio

	Net returns (Rs. ha^{-1})				B:C ratio			
Treatments	**40% PE**	**60% PE**	**80% PE**	**100% PE**	**40% PE**	**60% PE**	**80% PE**	**100% PE**
Without mulch	20698	74036	127840	111909	1.37	2.31	3.24	2.93
Straw mulch	19866	84258	120019	154146	1.29	2.23	2.74	3.46
Plastic mulch	45147	96619	147468	166973	1.70	2.48	3.23	3.50
SEm±	CD (P=0.05)				SEm±	CD (P=0.05)		
M at I	7066	21186			**M at I**	0.12		0.37
I at M	8025	24060			**I at M**	0.1310.47		

Interaction effect of irrigation levels and mulch

Results presented in (Table 2, 3 and 4) revealed that interaction effect of irrigation levels 100% PE + Plastic mulch were recorded highest *viz*., diameter of head (13.90 cm), average weight of marketable head (501.18 g plant^{-1}), yield (334.12 q ha^{-1}), net return (Rs. 166973 ha^{-1}) and B:C ratio (3.50), which were at par with 100% PE + Straw mulch and minimum values of all parameter were recorded under 40% PE + Without mulch. However, highest water use efficiency (8.78 q ha^{-1} cm^{-1}) was found with 80% PE + Plastic mulch. This finding is in close proximity with Tiwari *et al*. (2003) [11] and Subba *et al*. (2015) [10].

Conclusion

Finding of research work concluded that irrigation level at 100% PE recorded maximum yield and yield attributing characters, net returns and B: C ratio. However, all these parameters remained statistically at par with 80% PE. Among the mulches, the highest yield and yield attributing characters, water use efficiency, net returns and B: C ratio were recorded with plastic mulch. In interaction of irrigation levels and mulches, irrigation level at 100% PE with plastic mulch fetched appreciably higher yield (334.12 q ha^{-1}), net returns (Rs. 166973 ha^{-1}) and B: C ratio (3.50). While, highest water use efficiency (8.78q ha^{-1} cm^{-1}) was recorded 80% PE with plastic mulch.

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