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Evaluation of different weed management practices on growth and yield of cabbage (*Brassica oleracea* var. *capitata*.)

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Abstract
The cabbage head yield is reduced due to infestation of weeds at all the growth stages. To reduce the weed density in crop field by using different weed management practices, based on this a field experiment was conducted during *rabi* season 2016-2017 at College of Horticulture, Bidar, Karnataka, Indiato study the effect of different weed management practices on growth, yield and economics of cabbage. The treatment consist of T_1 [Pendimethalin 38.7 CS 0.7 kg a.i/ha (PE) +1 HW 30 DAT], T_2[Pendimethalin 30 EC 1.5 kg a.i/ha (PE)+1 HW 30 DAT], T_3 [Oxyfluorfen 23.5 EC 0.25 kg a.i./ha (PE]+1 HW 30 DAT), T_4] Alachlor 50 EC 1.5 ltra. i/ha (PE) +1HW 30 DAT], T_5 [Butachlor 50 EC 1.5 kg a.i/ha (PE) +1 HW 30 DAT], T_6 (HW at 25 and 50 DAT), T_7 (Weed free check) T_8 (Weedy check) were arranged in randomized block design with three replications. The results indicated that the weed free recorded maximum value of plant height (29.62cm), head maturity duration (61.33days) and yield attributing characteristics diameter of head(16.82cm), average head weight(1.63kg) and head yield(27.78 t/ha). It was followed by Pendimethalin 38.7 CS 0.7 kg a.i/ha (PE)+1 HW 30 DAT, Pendimethalin 30 EC 1.5 kg a.i/ha (PE)+1 HW 30 DAT, HW at 25 & 50 DAT. Maximum weed population (4.44), weed dry weight (1.08g) and weed index (70.69) was recorded with the treatment weedy check. Highest weed control efficiency (100%) was recorded with weed free. Maximum gross return (Rs.128514), net return (Rs.88496) was obtained with Pendimethalin 38.7 CS 0.7 kg a.i/ha (PE) +1 HW 30 DAT compared to rest of treatments. The application of Pendimethalin 38.7 CS 0.7 kg a.i/ha (PE) +1 HW 30 DAT was found better compared to rest of the treatments.

Keywords: Cabbage, weed control efficiency, weed index, head maturity, pendimethalin

Introduction
Cabbage (*Brassica oleracea* var. *capitata* L.) is one of the most popular vegetable crop among the cole crops. Cabbage belongs to family Brassicaceae and used for vegetable, curry, soup and pickle preparations. India ranks second in area and production of cabbage in the world after China. In India major cabbage growing states are west Bengal, Bihar, Maharashtra, Madhya Pradesh, Orissa, Gujarat and Haryana etc.

Cabbage is a very sensitive crop and needs more care to grow successfully than most of other vegetables. In India annually undergoes considerable loss due to various stresses of the agriculture and among these, weeds top the list by contributing 33% towards total loss. Weeds remove the available nutrients from soil in large quantity ranging from 30 to 40 per cent. Weeds interfere with crop plants severely reduce crop growth and lower yield and quality (Mal *et al.*, 2005) [7]. Although considerable research work has been carried out in India on various aspects of cabbage cultivation, the heavy manurial and frequent irrigation requirements of this widely spaced crop create conducive conditions for germination and growth of weeds, which reduce cabbage yield by 45-80%. Hand weeding, is an effective method of weed control but is laborious, time consuming, tedious, cost intensive and uneconomical under many situations. Herbicides have been very promising in controlling the weeds. No single herbicide is effective in controlling the wide range of weed flora and even continuous use of same herbicide may create resistance in weeds. Therefore, the present experiment was conducted to find out the efficacy of different weed management practices on the performance of cabbage.

Material and Methods
The field experiment was conducted during *rabi* season, 2016-17 at College of Horticulture, Bidar, Karnataka, India. The site is located at 17.91 ^{0}N, 77.52 ^{0}E Soil of the experimental field was red laterite. Latertic soils are pale to bright red in colour and clay to clayey loam in nature.

This soil has moderate to good infiltration characteristics. Eight treatment consisted T_1 [Pendimethalin 38.7 CS 0.7 kg a.i/ha (PE)+1 HW 30 DAT], T_2[Pendimethalin 30 EC 1.5 kg a.i/ha (PE)+1 HW 30 DAT], T_3 [Oxyfluorfen 23.5 EC 0.25 kg a.i./ha (PE)+1 HW 30 DAT], T_4 [Alachlor 50 EC 1.5 ltra.i/ha (PE) +1HW 30 DAT], T_5 [Butachlor 50 EC 1.5 kg a.i/ha (PE) +1 HW 30 DAT], T_6[HW at 25 and 50 DAT], T_7 [Weed free check] T_8 [Weedy check] were arranged in randomized block design with three replications.

The land was prepared by deep ploughing, harrowing and leveling and thereafter plots were prepared. The calculated quantities of fertilizers (150:100:125 N:P:K kg/ha) were applied to the each plot. The source of nutrients were nitrogen (DAP, Urea), phosphorus (DAP), potash (MOP). Half of nitrogen and whole dose of phosphorus and potash were applied as basal dose before transplanting of cauliflower seedlings. While the remaining half dose of nitrogen was given in 2 equal split doses, at 30 and 45 days after transplanting.

Healthy twenty five days old seedlings of uniform height were selected and transplanted in the field with the spacing of 60 X 45 cm. Irrigation was given immediately after transplanting and gap filling was done at 10 days after transplanting, to maintain the plant population in each plot and light irrigation was given just after gap filling of seedlings. The required amount of herbicides for the experimentation was calculated by using the following formula.

$$\text{Required chemical} = \frac{\text{a.i./ha x 100}}{\text{EC\%}}$$

Thus, spray of calculated amount of herbicide was done to each treatment plot using knapsack sprayer with a spray volume of 750 liters of water per hectare. The pre-emergence herbicides were applied as spray uniformly one days after transplanting of cabbage seedlings.

After transplanting, the cabbage seedlings were protected from insect-pests and diseases by spray of insecticide (Imidachlopride @ 0.3 ml/l of water) and fungicide (Carbandazime @ 2 gm/l of water) at an interval of 15 days. After complete development, the heads were harvested and observations were recorded on growth at different growth stage and yield parameters, marketable head yield and harvest index. Weed population, weed control efficiency, weed index was determined. The data obtained from the investigation were subjected to statistical analysis. The economics of different treatments was worked out on the basis of prices prevailing in the market for various inputs and produce.

Results and Discussion

Growth parameters

All the growth parameters recorded a significant effect of weed management practices (Table 1). Among the weed management practices, weed free treatment recorded maximum heightof plant at different growth stages followed by treatment Pendimethalin 38.7 CS 0.7 kg a.i/ha (PE)+1 HW 30 DATwhile the minimum value of all the growth parameters were recorded under weedy check. This increase in growth parameters could be due to lesser weed competition while lower in case of weedy check due to continuous competition of weeds which reduced the growth of plants due to poor exposure to sunlight and competition for nutrient and water. Similar results were reported by Mal *et al.* (2005) [7], Qasem (2009) [10] and Bana *et al.* (2012) [1] in cabbage.

Table 1: Plant population and plant height of cabbage as influenced by weed management practices

Treatment	Plant population (%)	Plant height (cm)			
		20 DAT	40 DAT	60 DAT	At harvest
T_1: Pendimethalin 38.7 CS 0.7 kg a.i/ha (PE)+1 HW 30 DAT	94.38	11.22	16.84	26.43	29.07
T_2: Pendimethalin 30 EC 1.5 kg a.i/ha (PE)+1 HW 30 DAT	91.03	10.36	15.55	24.41	26.85
T_3: Oxyfluorfen 23.5 EC 0.25 kg a.i./ha (PE)+1 HW 30 DAT	71.62	6.73	10.10	15.85	17.43
T_4: Alachlor 50 EC 1.5 ltra.i/ha (PE) +1HW 30 DAT	91.48	9.87	14.81	23.24	25.57
T_5: Butachlor 50 EC 1.5 kg a.i/ha (PE) +1 HW 30 DAT	92.39	9.78	14.67	23.02	25.33
T_6: HW at 25 and 50 DAT	92.84	10.41	15.62	24.53	26.98
T_7: Weed free check	94.66	11.43	17.15	26.93	29.62
T_8: Weedy check	46.25	6.05	9.08	14.26	15.68
S Em.±	3.00	0.63	1.02	1.77	2.23
C.D. at 5%	9.10	1.91	3.08	5.36	6.76
CV %	6.18	11.51	12.37	13.71	15.72

Phonological parameters

There was significant effect of weed management methods on days to 50% head initiation. Minimum days to 50% head initiation was noted in weed free treatment followed by Pendimethalin 38.7 CS 0.7 kg a.i/ha (PE)+1 HW 30 DAT. While the treatment weedy check had delayed 50% curd initiation (Table 2). This might be due to the control of weed infestation at early stage and less crop weed competition during the critical growth stage of the crop. These findings are in agreement with the result obtained by Bana *et al.* (2012) [1] in cauliflower and Kumar *et al.* (2014) [5, 6] in cabbage. Findings revealed significant effect of weed management practices on days to 50% maturity of head in Cabbage. Minimum days to 50% head maturity was taken by weed free followed by Pendimethalin 38.7 CS 0.7 kg a.i/ha (PE)+1 HW 30 DAT, Pendimethalin 30 EC 1.5 kg a.i/ha (PE)+1 HW 30 DAT, HW at 25 &50 DAT. While the weedy check had taken maximum days to attain 50% maturity of curd. Similar finding have been reported by Bana *et al.* (2012) [1] in cauliflower and Kumar *et al.* (2014) [5, 6] in cabbage. Headmaturity duration of cabbage significantly affected by weed management practices. The minimum head maturity duration recorded under the treatment Weed free check and it was followed by Pendimethalin 38.7 CS 0.7 kg a.i/ha (PE)+1 HW 30 DAT while maximum head maturity duration was observed under the treatment weedy check. This might be due to the excellent control of weed infestation at early stage and less crop weed competition during the critical growth stage of the crop. These results are in agreement with Bana *et al.* (2012) [1] in cauliflower.

Yield parameters

The minimum days required to head maturity, diameter of head, average head weight were recorded under the treatment weed free followed by weed free followed by Pendimethalin 38.7 CS 0.7 kg a.i/ha (PE) +1 HW 30 DAT, Pendimethalin 30 EC 1.5 kg a.i/ha (PE) +1 HW 30 DAT, hand weeding at 25 & 50 DAT. While the weedy check recorded maximum days required to head maturity, diameter of head, average head weight. Highest marketable head yield harvest index were recorded under the treatment T_2 (weed free) followed by T_7 (weed free) followed by Pendimethalin 38.7 CS 0.7 kg a.i/ha (PE) +1 HW 30 DAT, Pendimethalin 30 EC 1.5 kg a.i/ha (PE) +1 HW 30 DAT, hand weeding at 25 & 50 DAT, While the treatment T_8 (weedy check) recorded lowest marketable head yield (Table 5). This can be attributed to increase in plant growth and ultimately yield attributing character with reduced crop weed competition. The increased plant height directly responsible for increasing dry matter production. Higher synthesis and accumulation of photosynthates in the plant resulted in increasing the dry matter of crop and ultimately yield. Similar finding were also reported by Mal *et al.* (2005) [7], Qasem (2009) [10] and Bana *et al.* (2012) [1] in cauliflower, Nandal *et al.* (2005) [8] and Kumar *et al.* (2014) [5, 6] in cabbage.

Table 2: Yield parameters of cabbage as influenced by weed management practices

Treatment	Days to 50% head initiation (day)	Days required to head maturity (day)	Diameter of head (cm)	Average head weight (kg head^{-1})
T_1: Pendimethalin 38.7 CS 0.7 kg a.i/ha (PE)+1 HW 30 DAT	30.00	61.33	16.71	1.60
T_2: Pendimethalin 30 EC 1.5 kg a.i/ha (PE)+1 HW 30 DAT	30.67	63.00	16.39	1.29
T_3: Oxyfluorfen 23.5 EC 0.25 kg a.i./ha (PE)+1 HW 30 DAT	32.67	56.33	11.77	0.72
T_4: Alachlor 50 EC 1.5 ltra.i/ha (PE) +1HW 30 DAT	30.33	60.67	16.13	1.41
T_5: Butachlor 50 EC 1.5 kg a.i/ha (PE) +1 HW 30 DAT	30.33	61.33	15.90	1.40
T_6: HW at 25 and 50 DAT	30.33	60.67	16.00	1.46
T_7: Weed free check	29.33	61.33	16.82	1.63
T_8: Weedy check	33.67	55.33	10.91	0.63
S Em.±	1.29	2.38	0.88	0.69
C.D. at 5%	NS	7.23	2.67	0.21
CV %	7.24	6.88	10.10	9.36

Weed

Weed population, weed dry weight, weed control efficiency and weed index indicated remarkable influence of weed management practices (Table 3). Among the weed management practice, treatment T8 (weed free) was infested with minimum weed population followed by T1 [Pendimethalin 38.7 CS 0.7 kg a.i/ha (PE) +1 HW 30 DAT], T_2 [Pendimethalin 30 EC 1.5 kg a.i/ha (PE) +1 HW 30 DAT], T_6 (HW at 25 & 50 DAT). Maximum weed population was recorded in case of T_7 (weedy check) at all stages of crop growth. Similar results were also reported by Mal *et al.* (2005) [7], Bana *et al.* (2012) [1] and Kumar *et al.* (2015) [4] in cauliflower and Nandal *et al.* (2005) [8] in cabbage. Minimum weed dry weight was recorded by T_8 (weed free) which was followed by T1 [Pendimethalin 38.7 CS 0.7 kg a.i/ha (PE) +1 HW 30 DAT], T_2 [Pendimethalin 30 EC 1.5 kg a.i/ha (PE) +1 HW 30 DAT], T6 (HW at 25 & 50 DAT). Maximum weed dry weight was found in case of T_8 (weedy check). This might be due attributed to the fact that the data for dry weight of weeds were taken at the end of the season, where almost all of the weeds were present. These results are in line with Mal *et al.* (2005) [7] and Kumar *et al.* (2015) [4] in cauliflower and Kumar *et al.* (2014) [5, 6] in cabbage. Among the weed management practices, treatment T_8 (weed free) recorded maximum weed control efficiency. It was followed by T1 [Pendimethalin 38.7 CS 0.7 kg a.i/ha (PE) +1 HW 30 DAT], T_2 [Pendimethalin 30 EC 1.5 kg a.i/ha (PE) +1 HW 30 DAT], T6 (HW at 25 & 50 DAT), while the minimum value of weed control efficiency was recorded under the treatment T_8 (weedy check). It is apparent from the findings that those treatments which checked weed population and had lesser weed dry matter consequently resulted in higher weed control efficiency. These results are in conformity with those of Bana *et al.* (2012) [1], Kumar *et al.* (2014) [5, 6] and Kumar *et al.* (2015) [4] in cauliflower. Among the weed management practices T_7 (weed free) had lowest weed index which was followed by T1 [Pendimethalin 38.7 CS 0.7 kg a.i/ha (PE)+1 HW 30 DAT], T_2 [Pendimethalin 30 EC 1.5 kg a.i/ha (PE)+1 HW 30 DAT], T6 (HW at 25 & 50 DAT) while the maximum weed index was recorded with T_8 (weedy check). This could be described to the lower impact of weeds on yield under these treatments. These results are in line with those reported by Rathod *et al.* (2014) [11] and Gandolkar *et al.* (2015) [2] in onion.

Table 3: Weed control efficiency and weed index in cabbage as influenced by weed management practices

Treatment	Weed control efficiency (%)				Weed Index (%)
	20 DAT	40 DAT	60 DAT	At harvest	
T_1: Pendimethalin 38.7 CS 0.7 kg a.i/ha (PE)+1 HW 30 DAT	83.86	96.31	86.05	72.91	8.35
T_2: Pendimethalin 30 EC 1.5 kg a.i/ha (PE)+1 HW 30 DAT	82.11	95.65	83.99	71.62	15.55
T_3: Oxyfluorfen 23.5 EC 0.25 kg a.i./ha (PE)+1 HW 30 DAT	75.77	95.21	82.21	64.49	48.09
T_4: Alachlor 50 EC 1.5 ltra.i/ha (PE) +1HW 30 DAT	82.11	95.93	81.31	72.13	11.56
T_5: Butachlor 50 EC 1.5 kg a.i/ha (PE) +1 HW 30 DAT	82.54	96.04	81.82	70.42	10.38
T_6: HW at 25 and 50 DAT	80.10	89.47	91.64	65.92	9.94
T_7: Weed free check	100.00	100.00	100.00	100.00	0.00
T_8: Weedy check	0.00	0.00	0.00	0.00	70.69
S Em.±	4.18	3.51	2.66	2.93	5.41
C.D. at 5%	12.69	NS	8.08	8.90	16.40
CV %	9.89	7.29	6.08	7.86	42.92

Table 4: Total dry weight of weeds per 0.5 m^2 at different growth stages of cabbage as influenced by weed management practices

Treatment	Total dry weight of weeds (g)			
	20 DAT	40 DAT	60 DAT	At harvest
T_1: Pendimethalin 38.7 CS 0.7 kg a.i/ha (PE)+1 HW 30 DAT	0.52 (1.33)	0.37 (0.32)	0.52 (1.30)	0.67 (2.71)
T_2: Pendimethalin 30 EC 1.5 kg a.i/ha (PE)+1 HW 30 DAT	0.54 (1.48)	0.38 (0.39)	0.54 (1.49)	0.69 (2.85)
T_3: Oxyfluorfen 23.5 EC 0.25 kg a.i./ha (PE)+1 HW 30 DAT	0.60 (2.01)	0.39 (0.43)	0.57 (1.77)	0.74 (3.57)
T_4: Alachlor 50 EC 1.5 ltra.i/ha (PE) +1HW 30 DAT	0.54 (1.48)	0.38 (0.38)	0.57 (1.69)	0.68 (2.80)
T_5: Butachlor 50 EC 1.5 kg a.i/ha (PE) +1 HW 30 DAT	0.54 (1.45)	0.37 (0.36)	0.56 (1.64)	0.70 (2.96)
T_6: HW at 25 and 50 DAT	0.56 (1.65)	0.42 (0.63)	0.42 (0.60)	0.73 (3.42)
T_7: Weed free check	0.30 (0.00)	0.30 (0.00)	0.30 (0.00)	0.30 (0.00)
T_8: Weedy check	1.01 (8.29)	1.03 (8.84)	1.05 (9.22)	1.08 (10.05)
S Em.±	0.08	0.03	0.02	0.03
C.D. at 5%	0.11	0.07	0.09	0.10
CV %	7.82	9.76	8.09	8.35

Table 5: Cabbage yield, cost of cultivation, gross returns, net returns and BC ratio as influenced by weed management practices

Treatment	Head yield (t ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	BC ratio
T_1: Pendimethalin 38.7 CS 0.7 kg a.i/ha (PE)+1 HW 30 DAT	25.70	40018	128514	88496	3.21
T_2: Pendimethalin 30 EC 1.5 kg a.i/ha (PE)+1 HW 30 DAT	24.05	40430	120247	79817	2.97
T_3: Oxyfluorfen 23.5 EC 0.25 kg a.i./ha (PE)+1 HW 30 DAT	18.93	41757	94629	52872	2.27
T_4: Alachlor 50 EC 1.5 ltra.i/ha (PE) +1HW 30 DAT	24.91	40430	124568	84138	3.08
T_5: Butachlor 50 EC 1.5 kg a.i/ha (PE) +1 HW 30 DAT	25.16	40070	125802	85732	3.14
T_6: HW at 25 and 50 DAT	23.62	52930	118085	65155	2.23
T_7: Weed free check	27.78	64930	138900	73970	2.14
T_8: Weedy check	13.38	38930	66900	27970	1.72
S Em.±	2.71	-	-	-	-
C.D. at 5%	8.22	-	-	-	-
CV %	20.45	-	-	-	-

Table 6: Total weed count per 0.5 m^2 at different growth stages of cabbage as influenced by weed management practices

Treatment	Total weed count (No. 0.5m^2)			
	20 DAT	40 DAT	60 DAT	At harvest
T_1: Pendimethalin 38.7 CS 0.7 kg a.i/ha (PE)+1 HW 30 DAT	1.74 (2.55)	1.06 (0.62)	1.71 (2.49)	2.38 (5.18)
T_2: Pendimethalin 30 EC 1.5 kg a.i/ha (PE)+1 HW 30 DAT	1.82 (2.83)	1.12 (0.75)	1.83 (2.85)	2.44 (5.45)
T_3: Oxyfluorfen 23.5 EC 0.25 kg a.i./ha (PE)+1 HW 30 DAT	2.08 (3.84)	1.15 (0.82)	1.96 (3.38)	2.70 (6.82)
T_4: Alachlor 50 EC 1.5 ltra.i/ha (PE) +1HW 30 DAT	1.82 (2.83)	1.11 (0.73)	1.93 (3.22)	2.42 (5.34)
T_5: Butachlor 50 EC 1.5 kg a.i/ha (PE) +1 HW 30 DAT	1.80 (2.76)	1.09 (0.68)	1.90 (3.14)	2.48 (5.66)
T_6: HW at 25 and 50 DAT	1.91 (3.14)	1.31 (1.21)	1.28 (1.15)	2.65 (6.53)
T_7: Weed free check	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T_8: Weedy check	4.04 (15.84)	4.17 (16.88)	4.26 (17.62)	4.44 (19.19)
S Em.±	0.12	0.07	0.12	0.10
C.D. at 5%	0.36	0.23	0.37	0.31
CV %	10.26	8.82	10.90	6.90

Economics

The viability of any practices is evolved on the basis of experimentation and depends upon its economic feasibility. A best treatment, if not fetching appropriate monetary returns, may not be acceptable to farmers. With a view to evaluate various treatments in terms of economic return, the marketable yield of the crop converted in to monetary returns. Highest gross income and net income was found with weed management practices T_8 (weed free) followed by T1 [Pendimethalin 38.7 CS 0.7 kg a.i/ha (PE) +1 HW 30 DAT], but the highest B:C ratio was found under treatment T1 [Pendimethalin 38.7 CS 0.7 kg a.i/ha (PE) +1 HW 30 DAT], followed by treatment T_7 (weed free). The results are in agreement with Bana *et al.* (2012) [1] and Kumar *et al.* (2015) [4] in cauliflower and Nandal *et al.* (2005) [8] in cabbage.

Conclusion

The results thus amply demonstrate that for attaining increased growth, yield attributes and yield of Cabbage with lower weed population can be attained with the application of Pendimethalin 38.7 CS 0.7 kg a.i/ha (PE)+1 HW 30 DAT along with the increased monetary returns per rupee invested.

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