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Effects of weed management practices on soil microbial dynamics and yield of cabbage (*Brassica oleracea* var. *capitata* L.)

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Abstract
A field experiment was to study the effect of different weed management practices on Soil microflora and yield attributes and economics of cabbage. The results indicated that the T_7 (weed free) recorded maximum value of plant height and earliest 50% head initiation, head maturity duration and yield attributing characteristics diameter of head, average head weight and head yield. It was followed by 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_6 (HW at 25 & 50 DAT). The number of bacterial, fungi and actinomycetes population was recorded with the treatment T_8 (weedy check) compared to rest of the population. No significant difference noticed among the herbicide treatments. Beyond 40 days after application of herbicides and up to harvest, the population increased considerably in each case justifying no long term adverse effect of herbicides on the beneficial soil micro fauna and flora. The bacterial population was adversely affected, followed by fungi and actinomycetes in descending order. But at the time of harvest of the crop, the microbial population attained with all the treatments, the level equal to that of initial level or even more than original level in some treatments. The trend was similar in bacteria, fungi and actinomycetes. It is clear that the effect of herbicides on soil microbes is only temporary. The adverse effects of herbicides were gradually reduced with passage of time and practically, there was no adverse effect of herbicides on soil microbial activities in terms of fungi, bacteria and actinomycetes population after harvest of cabbage. Maximum gross return, net return was obtained with [Pendimethalin 38.7 CS 0.7 kg a.i/ha (PE)+1 HW 30 DAT] compared to rest of treatments.

Keywords: Soil microflora, weed index, head initiation, head maturity

Introduction
Cabbage (*Brassica oleracea* var. *capitata* L.) is one of the most popular vegetablecrop among the cole crops. Cabbage belongs to family Brassicaceae. Weeds are harmful or obnoxious and troublesome for proper growth and development of winter maize. They have strong competition with crop for sun light, water, nutrients, space and other growth factors. Their eradication through use of manual labour not only costly and time taking but also there is not easy availability of labour at the time of requirement. Therefore, use of suitable herbicides would be better substitute from economic point of view. Ramesh and Nadanassababady (2005) [23] found that significant differences in population of soil bacteria, fungi and actinomycetes were noticed shortly after application of herbicides i.e. 5 days after sowing as compared to their population before herbicide application which was in conformity with the results of Jing *et al.*, (2010) [17].

Herbicides applied in crop fields for weed control are reported to have affected the soil microorganisms living in soil and also in the rhizosphere of crops and weeds. There was a temporary setback in microbial population due to application of herbicides and microbes adopted themselves to the new substrate to grow normally 25 days after herbicide application. The population of soil heterotrophs was affected with herbicide application and these adverse effects reduced gradually with the passage of time, up to 20 days of application of pre-emergence herbicides, there was a decrease in bacterial, fungal and actinomycetes population and after 30 days, the microbes multiplied to their original number.

Use of herbicides in agriculture system may usually disturb and alter the biological equilibrium in soil (Grossbard, 1976) [16]. Sandor (2006) [27] reported that herbicides decreased the number of total viable bacteria and microscopic fungi. The population of nitrifying bacteria and cellulose degrading bacteria increased significantly. Field doses of herbicides are often safe for soil microbes but their response to herbicide application cannot be predicted for all environments. This is because of the herbicide-microbe interaction depends not only on molecular configuration of herbicide, but also on many soil and climatic factors like temperature, soil moisture and acidity. Keeping in view, the present investigation was carried out to find out the effect of chemical herbicides on soil microorganisms population to be studied thoroughly for effective use in soil for better adoption of weed control measures to combat the menace of weeds in cabbage.

Materials and Methods

The field experiment was conducted during rabi season, 2016-17 at College of Horticulture, Bidar (Karnataka). Soil of the experimental field was red laterite. 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 there after plots were prepared. The calculated quantities of fertilizers 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. Pure and 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. The methods employed for analyzing the microbial properties of the experimental soil before treatment and at harvest were performed. Soil samples from the experimental plots were collected from the space between the rows at a depth up to 0-15 cm on different dates *viz.*, initial (pre-treatment), 30, 60 day after transplanting (DAT) and at harvest stage of the crop. The soil samples from different replicates for the same weed control treatment were pooled together and then composite soil samples of each herbicidal treatment were taken for microbial analysis by using dilution plate technique following standard methods. Soil dilutions were prepared in sterile distilled water by constant shaking and plating was done separately in replicates in specific media like for bacteria-Thornton's agar medium, 1922 at 10^{-7} dilutions, for fungi-Martin'rose Bengal streptomycin agar medium, 1950 at 10^{-5} dilutions and for actinomycetes- Jensen's agar medium, 1930 at 10^{-4} dilutions. The plates were incubated at 28^0 1^0C for maximum duration of 7 days in BoD incubator and observations in terms of counting of number of colonies per plate were made. After complete development, the heads were harvested and observations were recorded on yield parameters, head yield and harvest index. 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.

Result and Discussion

Soil bacteria counts (CFU x 10^7 g^{-1} oven dry soil)

Data on the population of bacteria in soil at different intervals of growth stages of the crop is presented in Table 1. There was no significant difference in the initial population of total bacteria in different treatments. However, all the tested herbicides showed significant influence on the population of total bacteria in rhizosphere soil of cabbage up to 30 days after application of herbicides showing soil bacterial population in lower. Reduction in their population occurred in all the herbicide treated plots up to that period over the weed free and weedy check. Thereafter, bacteria population was gradually increasing at subsequent time intervals *viz.* 30 DAT, 60 DAT and at harvest, their population increased considerably in herbicidal treated plots though the weed free and weedy check showed higher bacteria population than other herbicide treated plots. Initially the bacteria population in weedy free check plot (T_7) was lower over weedy check (T_8), however, it remain continued superior value for rest of the time intervals and harvest. But at harvest, the data showed that their population decreased considerably in herbicide treated plots and lower than the initial population of bacteria. Olabode *et al.*, (2010) [22] reported that response of soil microorganisms to atrazine doses varied depending upon herbicides. Bacterial population was inversely related to atrazine doses with the highest value for control (290 x 10^6 cfu g^{-1} soil) and the least in 100% recommended dose (29 x 10^6 cfu g^{-1} soil). Fungi and actinomycetes, however, showed a similar trend. Jing *et al.*, (2010) [17] reported that an experiment was conducted to determine acetochlor effect on soil microbial activity and indicated that number of bacteria and actinomycetes increased two weeks after applying acetochlor, then inhibited by acetochlor @ 30 mg kg^{-1} at 30th day. After that, actinomycetes population recovered while bacteria population was still inhibited till 60th day. Fungi population decreased at 14th day after applying acteochlor, but then recovered at 30th day and was stimulated at 60th day.

Soil fungi counts (CFU x 10^5 g^{-1} oven dry soil)

Data on the population of fungi in soil at different time intervals of the crop presented in Table 1. There was no significant difference in the initial population of fungi in different treatments. However, all the tested herbicides treatments showed significant adverse effect on the population of fungi in rhizosphere soil of cabbage up to 30 days after transplanting exhibiting soil fungi population in lower range. Reduction in their population occurred in all herbicide treated plots up to that period over the weed free and weedy check. Thereafter, fungi population was gradually increasing at subsequent time intervals. Their population increased considerably in herbicidal treated plots though the weed free (T_8) and weedy check (T_7) exhibited higher value of fungi population than other herbicide treated plots. Initially the bacteria population in weedy free check plot (T_7) was lower over weedy check (T_8), however, it remain continued superior value for rest of the time intervals and harvest. But at harvest, the data showed that their population decreased considerably in herbicide treated plots and lower than the initial population of bacteria. Li *et al.,* (2005) [20] revealed that acetochlor at high concentrations of 150 and 250 mg kg^{-1} had an acute and chronic toxicity on both soil fungal population and total fungal biomass, but at a low concentration of 50 mg kg^{-1} had stimulating effect that was stronger with total fungal biomass than with soil fungal population. Cal *et al.,* (1993) [14] reported that atrazine and alachlor herbicides decreased fungal populations without altering bacterial population. Konstantinovic *et al.,* (1999) [18] reported that alachlor/atrazine herbicides reduces the population of bacteria and increases the population of fungi and actinomycetes. Alachlor was generally more inhibiting towards the microbes as compared to atrazine. Increased herbicide doses increased the inhibitory effect, which was best exhibited at the beginning of the growing period.

Soil actinomycetes counts (CFU x 10^5 g^{-1} oven dry soil)
Data on the population of actinomycetes in soil at different intervals of growth stages of crop is presented in Table 1. All the herbicide treatments showed significant influence on the population of actinomycetes in rhizospheric soil of cabbage indicating in lower range with increasing herbicide doses. Like the bacteria and fungi, no significant difference in initial population of actinomycetes in different plots was observed. However, significant differences were recorded between herbicide treated plots, weed free and weedy check plot after 30 days after application of herbicide.

Table 1: Bacterial population in soil at different growth stages of cabbage as influenced by weed management practices

Treatment	Bactrial (x 10^7 Cfu g^{-1} of soil)				Fungi (x 10^5 Cfu g^{-1} of soil)				Actinomycetes (x 10^4 Cfu g^{-1} of soil)			
	Initial	30DAT	60DAT	At Hatvest	Initial	30DAT	60DAT	At Hatvest	Initial	30DAT	60DAT	At Hatvest
T_1	37.77	25.06	30.07	20.05	18.89	20.05	22.05	14.70	20.78	23.56	25.86	17.91
T_2	36.39	24.59	29.50	19.67	18.20	19.67	21.63	14.42	20.01	22.62	24.88	16.59
T_3	35.69	17.66	21.19	14.13	17.85	14.13	15.54	10.36	19.63	16.25	17.87	11.91
T_4	35.06	24.20	29.04	19.36	17.53	19.36	21.30	14.20	19.28	22.26	24.49	16.33
T_5	35.80	23.85	28.61	19.08	17.57	19.08	20.98	13.99	19.33	21.94	24.13	16.09
T_6	34.10	24.00	28.80	19.20	17.05	19.20	21.12	14.08	18.76	22.08	24.29	16.19
T_7	35.49	25.23	30.27	20.18	17.75	20.18	22.20	14.80	19.52	23.21	25.53	17.02
T_8	34.55	31.70	32.09	21.36	17.28	21.38	23.41	15.94	18.99	24.29	26.52	18.34
S Em.±	1.14	1.42	1.86	1.34	0.57	1.14	1.30	0.86	0.61	1.42	1.40	1.09
C.D. at 5%	NS	4.32	5.66	5.08	NS	3.46	3.96	2.61	NS	4.33	4.31	3.32

Yield parameters
There was significant effect of weed management methods on days to 50% head initiation. Minimum days to 50% head initiation was taken in treatment T7 (weed free) followed by T1[Pendimethalin 38.7 CS 0.7 kg a.i/ha (PE)+1 HW 30 DAT]. While the treatment T_8 (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 T_7 (weed free) 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 T8 (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 T7 and it was followed by T1 [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 T8 (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.

The minimum days required to head maturity, diameter of head, average head weight were recorded under the treatment T_2 (weed free) followed by T_7 (weed free) 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 T_8 (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 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 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 (2007) [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

Shortly after application of herbicides (5 days after sowing) significant differences in population of soil microorganisms (bacteria, fungi, actinomycetes) was noticed as compared to their pulation before herbicide application which was in conformity with the results of Jing *et al.*, (2010) [17]. Such inhibitory effect of herbicides used in the study persisted upto 30 days after transplanting of the crop The trend was similar in bacteria, fungi and actinomycetes. It is clear that the effect of herbicides on soil microbes is only temporary.

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.

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	-	-	-	-

On the basis of present experiment, it may be concluded that the maximum values, yield attributes, yield of Cabbage and lower weed population as well as maximum gross and net returns were recorded with treatment T_7 (weed free) followed by treatment 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). But highest B:C ratio(1:3.68) was obtained with treatment T1 [Pendimethalin 38.7 CS 0.7 kg a.i/ha (PE)+1 HW 30 DAT]. There was also no ill impact of herbicidal treatments on the soil microbial activities in terms of fungi, bacteria and actinomycetes population after harvest of cabbage.

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