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Effect of Non-Chemical Weed Management Approaches on Yield and Nutrient Uptake in High Density Planting of Cotton in *Vertisol* of Northern Karnataka

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

In order to investigate the impact of non-chemical eco-friendly weed management strategies on the yield, nutrient uptake, and soil balance of high density planting cotton in deep vertisols, a field experiment was carried out in 2017 and 2018 at the Department of Agronomy, College of Agriculture, UAS, Raichur. Three replications were used in the experiment's Randomized Completely Block Design layout. There were 14 different interventions used, including polythene mulch, paddy straw mulch, cotton stalk mulch, intercropping with green manures at a 1:1 ratio (sunnhemp and cowpea), four different botanical extracts at 20% as PE (Eucalyptus sp., Prosopis juliflora extract, Cassia tora, and Parthenium hysterophorus), mechanical, cultural, and their combination, in comparison to weed-free check. Three replicated randomised complete block design was used to conduct the experiment. The two years pooled data showed that, compared to the other treatments, weed free check had a significantly higher seed cotton production (1,722 kg /ha). It was then followed by Cotton + Sunnhemp (1:1) in-situ mulching at 45 DAS (1299 kg /ha), pendimethalin 38.7 CS @ 680 g a.i./ha as PE fb pyrithiobac sodium 10 EC 75 g a.i./ha + quizolofop ethyl 37.5 g a.i./ha at 25 DAS as PoE (1274 kg /ha), The environmentally friendly treatments, such as cotton + sunnhemp (1:1) and in-situ mulching at 45 DAS,

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mulching with black polythene sheet, cotton + cowpea (1:1) and in-situ mulching at 45 DAS, and others, were on par with weed free check and may be suggested since they were the best options.

Keywords: HDPS (High density planting system); nutrient uptake; seed cotton yield.

1. INTRODUCTION

The important commercial fibre crop cotton (Gossypium sp.), also referred to as "the white gold or the king of fibre crops, is grown all over the world under various agro-climatic conditions. With a productivity average of 560 kg lint per hectare, Karnataka ranks eighth in cotton area (5.46 lakh ha) and seventh in production (18.0 lakh bales) [1]. Weed control is regarded as a crucial step for gaining higher productivity among the various agronomic manipulations that could affect cotton productivity [2]. During the early stages of crop growth, weeds compete more for nutrients, moisture, and sunlight than at later stages. At the early growth phases, weeds absorb 5 to 6 times the nitrogen, 5 to 12 times the phosphorus, and 2 to 5 times the potash of cotton crops, which can be particularly detrimental to cotton production systems. Cotton weed competition crucial time was discovered to be between 15 and 60 days [3]. Therefore, if appropriate weed management procedures are taken, there will be more nutrients and moisture available for the crop's benefit. Manual weed control is time-consuming and expensive. Despite the fact that herbicides are excellent at boosting yield, uncontrolled use of them has had negative ecological effects, including the emergence of weeds that are resistant to them and changes in weed population. Finding more effective alternatives to chemical weed management in various crops has recently been the focus of research. One of the main objectives of modern agriculture is to use less herbicides, and the hunt for more effective weed control methods that are affordable, secure, and sustainable is given a lot of attention.

Therefore, weed control methods using plant extracts rather than pesticides result in less aftereffects. Additionally, farmers search for broad spectrum, post-emergence herbicide/herbicide combinations that are selective. The use of extracts for weed control is thought to be efficient, affordable, and eco-friendly [4]. Intercropping is encouraged without reducing cotton production because to the delayed initial development and uncertain growth behaviour. The potential of intercropping to increase unit profitability while not disrupting the cotton ecosystem is unmatched. Intercropping is the practise of growing two or more crops concurrently in different rows on the same plot of land in order to more effectively use the resources at hand and increase productivity per unit area [5]. With the least amount of competition, two crops that differ in their capacity to root, nutritional needs, height, and canopy thrive simultaneously [6]. Intercropping may significantly reduce weed density and biomass [7]. Growing companion plants that are specifically allelopathic to weeds may be a more cost-effective option than using synthetic herbicides, according to Singh et al. [8]. This research was done to examine the effects of non-chemical weed control methods on the yield, nutrient uptake, and soil balance of high density cotton plantings in deep vertisols.

2. MATERIALS AND METHODS

In the years 2017–18 and 2018–19, an experiment was carried out in the Department of Agronomy, College of Agriculture, UAS, Raichur. Three replications of the experiment were used in its randomised completely block design. At first, available nitrogen (148.4 kg /ha), available phosphorus (54.3 kg /ha), available potassium (549.8 kg /ha), organic carbon (0.55%), pH (8.21), and EC values were reported for the soil (0.31 dsm-1). Additionally, weather data is logged and displayed in Fig. 1. The fourteen treatments included black polythene mulching, cotton stalk mulching at 5 t/ha, paddy straw mulching at 5 t/ha, cotton + hemp mulching at 1:1 and in situ mulching at 45 DAS, and cotton + cowpea mulching at 1:1 and in situ mulching at 45 DAS. Weeding with a cycle weeder at 25, 50, and 75 DAS, HW at 25, and IC at 50 and 75 DAS, Eucalyptus sp. extract @ 20% as PE fb IC at 50 and 75 DAS, Prosopis juliflora extract @ 20% as PE fb IC at 50 and 75 DAS, Cassia tora @ 20% as PE fb IC at 50 and 75 DAS, *Parthenium hysterophorus* extract 20% as PE fb IC at 50 and 75 DAS, Pendimethalin 38.7 C S at 680 g a.i./ha as PE + quizolofop ethyl 37.5 g a.i./ha at 25 DAS as PoE, weed free check, and unweeded control. The recommended fertiliser dosage and spacing for cotton were correspondingly maintained for all treatments at 80:40:40 NPK kg/ha and 60 cm x 20 cm. Sunnhemp and cowpea intercropping were grown and in situ mulched at 45 DAS, and other herbicide chemicals are employed as pre-emergence and post-emergence as per the treatment instructions. Treatments such as polythene sheet mulch, cotton stalk mulch, and paddy straw mulch were mulched at the time of sowing. Fresh leaves from plants including Eucalyptus species, Prosopis juliflora, Cassia tora, and Parthenium hysterophorus are cut into small species, soaked overnight in a 1:1 mixture of alcohol and water, and then dried. The soaking leaves were pulverised using a mixer grinder after 12 hours. By filtering the paste, a leaf extract representing a 100% stock solution of each botanical species was created. A 20% concentration was made from the stock solution and sprayed in accordance with the treatment plan. The samples of weeds utilised for nutritional analysis were gathered to estimate dry matter production at maturity. The crop samples were pulverised in a Willey mill and utilised to calculate the intake of important nutrients by estimating the amounts of N, P, and K.

2.1 Nutrient uptake (kg /ha)

After digesting the samples with H2SO4 and H2O2, the nitrogen content (%) in the plant and weed samples was calculated using the micro Kjeldahl method using the Kelplus N analyzer [9]. The tri-acid (HNO3, HCLO4, and H2SO4) in the ratio of (9:3:1), respectively digested plant and weed samples, were examined for phosphorus using Vanado-molybdo phosphoric acid. Utilizing a spectrophotometer set at 420 nm, the amount of yellow colour generated was measured [9]. A flame photometer was used to determine the tri-potassium acid's content [9].

Nutrient uptake = Nitrogen / phosphorus / potassium of plant parts / weeds x weight of seed cotton yield (kg /ha) / weeds weight

2.2 Data Analysis

To ascertain the impact of time and rate of application of herbicides on weed species, lint yield, and nutrient uptake by weeds and crop, analysis of variance (ANOVA) for the randomised complete block design was carried out. For all analyses, SAS 9.3 (SAS Institute, Cary, NC, USA 2008) was used. If the ANOVA for the multi-year combined data indicated a significant effect between treatments and years, a separate ANOVA was run for each individual year.

3. RESULTS AND DISCUSSION

3.1 Weed Flora at Experimental Site

Among the grasses found at the experimental site were Cynodon dactylon, Rottboellia exaltata, and Echinochloa colonum, as well as Dactyloctenium aegyptium. The only sedge that was present in the field was Cyperus rotundus. There were several broad-leaved weeds that were visible in the field, including Parthenium hysterophorus, Euphorbia geniculata, Trianthema portulacastrum, Trichodesma indica, Cyanotis cristata, Digera arvensis, and Celosia argentea. The yield is impacted by weeds' competition with crops for moisture, nutrients, light, and CO2. As a result, it is crucial to assess the crop's nutrient intake in order to quantify the impact of the control measures.

3.2 Nitrogen, Phosphorus and Potassium Nutrient Uptake (kg /ha) by Weeds

3.2.1 Nitrogen uptake by weeds

The outcome showed that the weed-free check recorded much lower than the other treatments. Pendimethalin 38.7 CS @ 680 g a.i. /ha application as PE fb pyrithiobac sodium 10 EC @ 75 g a.i. /ha + quizolofop ethyl 5 EC @ 37.5 g a.i. /ha + quizolofop ethyl 5 EC @ 37.5 g a.i. /ha at 25 DAS as POE (4.2 kg /ha (5.4 kg /ha) detected noticeably less nitrogen uptake compared to the unweeded control.

3.2.2 Phosphorus uptake by weeds

In comparison to the unweeded control, the treatment, weed-free check, recorded a much decreased removal of phosphorus by weeds (0 kg /ha). Application of pendimethalin 38.7 CS @ 680 g a.i. /ha as PE fb pyrithiobac sodium 10 EC @ 75 g a.i. /ha + quizolofop ethyl 5 EC @ 37.5 g a.i. /ha at 25 DAS as POE, black polythene sheet mulch, cotton + sunnhemp (1:1) and then in situ mulching at 45 DAS, cotton (2.8 kg /ha).

3.2.3 Potassium uptake by weeds

The weeds intake of potassium was comparable to their uptake of nitrogen and phosphate. Application of pendimethalin 38.7 CS @ 680 g a.i. /ha as PE fb pyrithiobac sodium 10 EC @ 75 g a.i. /ha + quizolofop ethyl 5 EC @ 37.5 g a.i. /ha at 25 DAS as POE, black polythene sheet mulching, cotton + sunnhemp (1:1) and in situ mulching at 45 DAS, cotton + cowpea (1:1) and then in situ mulching at 45 DAS, weeding with cycle weeder at 25, 50 and 75 DAS and HW at 25 DAS and IC at 50 and 75 DAS (5.9, 6.6, 6.2, 6.5, 7.2 and 7.1 kg /ha, respectively) were on par with each other and superior over unweeded control (20.4 kg /ha).

Among weed control strategies, pendimethalin 680 g a.i.//ha combination application at the beginning of crop growth and fb pyrithiobac sodium 10 EC @75 g a.i. /ha + quizolofop ethyl 5 EC @ 37.5 g a.i. /ha at 25 DAS as POE were found to reduce nutrient loss by weeds. This may be because weeds were largely absent throughout the early stages of crop development and because the PE and POE pesticide applications, which inhibited weeds' ability to produce dry matter, creating a weed-free environment.

These results are consistent with Sathishkumar's reports [10]. In situ mulching of green manures, intercropping, and black polythene sheet mulching all exhibited less nutrient loss by weeds than the unweeded control. The efficient management of dominating grasses, sedges, and broad-leaved weeds by shading and also by suppressing weeds by lowering competition for natural resources such as light, water, nutrients, and applied fertilisers for their better growth contributed to the reduced uptake of nutrients by weeds. This weed-free environment encouraged cotton to grow rapidly, supported the crop at all crucial stages to produce more DMP, and controlled weed in the crop's later stages of development. Hand weeding during a later era has led to higher WCE and less nitrogen uptake by weeds as a result of the removal of weeds. However, weed removal of nutrients from the soil was greatest in the unweeded control. High weed density and increased weed dry weight buildup contributed to the controlled weeds' increased intake of nutrients, supporting prior findings by Malarkodi [11]. The higher nutrient uptake by weeds may be caused by the higher weed intensity and biomass in the unweeded control treatment as well as its superiority in using sunlight, moisture, and CO2 over plants, which results in the accumulation of more dry matter by weeds and, as a result, the absorption of nutrients from the soil, whereas the reduced nutrient uptake by weeds was caused by less weed dry matter in the respective treatments. The findings of Anjum et al. [12] and Veeramani *et al.* [13] were very similar to these results (Table 1).

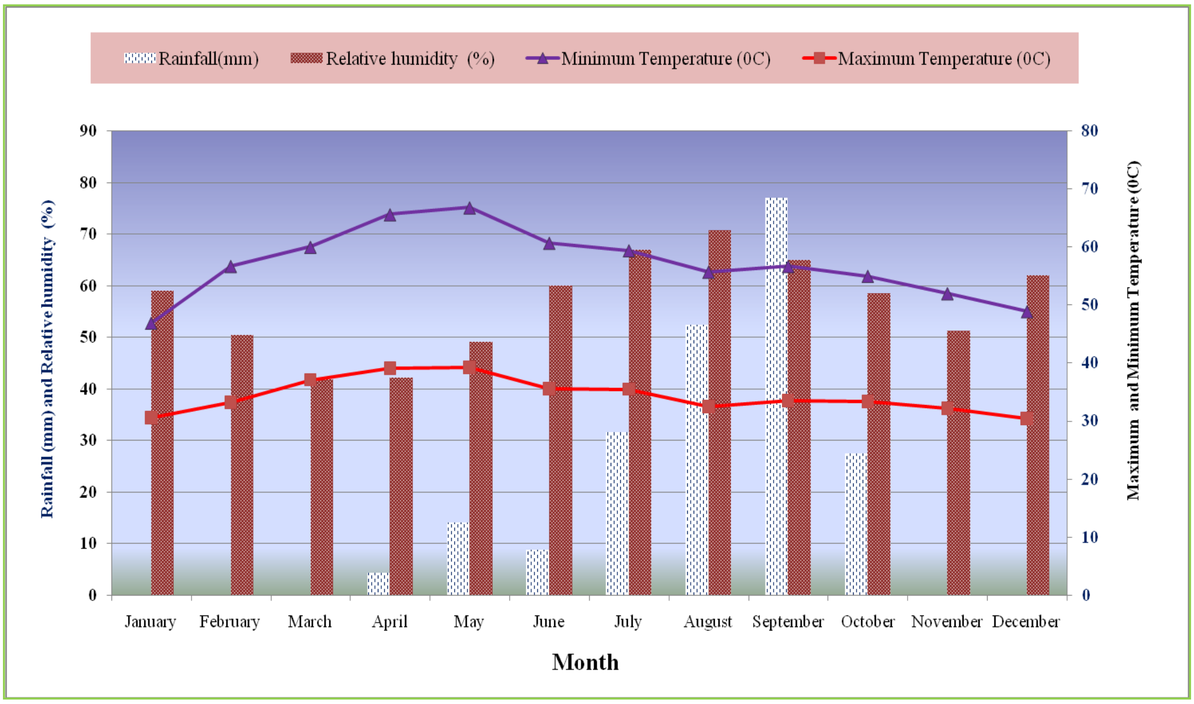

Fig. 1. Monthly meteorological data for the year 2018 at Main Agricultural Research Station, Raichur

Table 1. Nitrogen, Phosphorus and potassium uptake by weeds as influenced by different non-chemical eco-friendly weed management practices in HDPS cotton

Treatment	**N uptake (kg /ha)**			**P uptake (kg /ha)**			**K uptake (kg /ha)**		
	2017	**2018**	**Pooled**	**2017**	**2018**	**Pooled**	**2017**	**2018**	**Pooled**
Mulching with black polythene	4.6	6.2	**5.4**	0.7	0.9	**0.8**	6.2	6.9	**6.6**
Mulching with cotton stalk at 5 t /ha	8.6	8.8	**8.7**	1.2	1.1	**1.2**	9.3	9.8	**9.6**
Mulching with paddy straw at 5 t /ha	8.7	8.2	**8.5**	1.1	1.2	**1.2**	8.6	9.4	**9.0**
Cotton + Sunnhemp (1:1) and *in situ* mulching at 45 DAS	3.6	5.5	**4.6**	0.6	0.7	**0.7**	6.0	6.4	**6.2**
Cotton + Cowpea (1:1) and *in situ* mulching at 45 DAS	4.4	5.8	**5.1**	0.7	0.8	**0.7**	6.2	6.7	**6.5**
Weeding with cycle weeder at 25, 50 and 75 DAS	4.6	7.2	**5.9**	0.7	0.8	**0.8**	6.4	8.0	**7.2**
HW at 25 DAS and IC at 50 and 75 DAS	4.4	6.4	**5.4**	0.7	0.8	**0.7**	6.3	7.8	**7.1**
Eucalyptus extract @ 20 % as PE *fb* IC at 50 and 75 DAS.	7.2	9.0	**8.1**	1.2	1.2	**1.2**	9.1	9.2	**9.2**
Prosopis juliflora extract @ 20 % as PE *fb* IC at 50 and 75 DAS.	9.0	10.2	**9.6**	1.3	1.3	**1.3**	9.7	9.5	**9.6**
Cassia tora @ 20 % as PE fb IC at 50 and 75 DAS.	8.8	10.0	**9.4**	1.3	1.3	**1.3**	9.4	9.6	**9.5**
Parthenium extract 20 % as PE *fb* IC at 50 and 75 DAS.	8.9	10.4	**9.7**	1.3	1.3	**1.3**	9.5	9.7	**9.6**
Pendimethalin 38.7 CS @ 680 g *a.i.* /ha as PE *fb* pyrithiobac sodium 10 EC 75 g *a.i.* /ha + quizolofop ethyl 5 EC @ 37.5 g *a.i.* /ha at 25 DAS as PoE.	3.6	4.7	**4.2**	0.6	0.7	**0.6**	5.3	6.5	**5.9**
Weed free check	0.0	0.0	**0.0**	0.0	0.0	**0.0**	0.0	0.0	**0.0**
Unweeded control	18.7	24.2	**21.5**	2.5	3.2	**2.9**	17.8	22.9	**20.4**
S.Em±	**0.5**	**1.0**	**0.6**	**0.1**	**0.1**	**0.1**	**0.4**	**1.0**	**0.6**
C.D. at 5%	**1.3**	**2.9**	**1.7**	**0.2**	**0.2**	**0.3**	**1.2**	**2.8**	**1.6**

Table 2. Nitrogen, phosphorus and potassium uptake by high density planting cotton as as influenced by different non-chemical eco-friendly weed management practices

Treatment	N uptake(kg /ha)			P uptake(kg /ha)			K uptake(kg /ha)		
	2017	**2018**	**Pooled**	**2017**	**2018**	**Pooled**	**2017**	**2018**	**Pooled**
Mulching with black polythene	87.0	90.5	**88.8**	10.6	10.4	**10.5**	79.0	79.7	**79.4**
Mulching with cotton stalk at 5 t /ha	70.2	72.6	**71.4**	9.0	9.0	**9.0**	65.6	65.6	**65.6**
Mulching with paddy straw at 5 t /ha	82.0	76.7	**79.4**	9.4	9.2	**9.3**	67.4	62.8	**65.1**
Cotton + Sunnhemp (1:1) and *in situ* mulching at 45 DAS	95.8	91.9	**93.9**	10.6	11.0	**10.8**	82.0	82.2	**82.1**
Cotton + Cowpea (1:1) and *in situ* mulching at 45 DAS	92.2	88.6	**90.4**	10.2	10.8	**10.5**	79.4	80.0	**79.7**
Weeding with cycle weeder at 25, 50 and 75 DAS	84.0	85.9	**85.0**	9.7	10.4	**10.1**	76.4	77.2	**76.8**
HW at 25 DAS and IC at 50 and 75 DAS	89.3	87.3	**88.3**	9.9	10.9	**10.4**	76.8	79.2	**79.0**
Eucalyptus extract @ 20 % as PE *fb* IC at 50 and 75 DAS.	75.1	78.6	**76.9**	9.4	9.5	**9.5**	74.0	73.3	**73.7**
Prosopis juliflora extract @ 20 % as PE *fb* IC at 50 and 75 DAS.	75.8	77.8	**76.8**	8.9	9.1	**9.0**	72.7	70.6	**71.7**
Cassia tora @ 20 % as PE fb IC at 50 and 75 DAS.	75.6	75.5	**75.6**	9.0	9.2	**9.1**	72.0	72.0	**72.0**
Parthenium extract 20 % as PE *fb* IC at 50 and 75 DAS.	75.3	75.6	**75.5**	8.7	9.2	**9.0**	72.5	71.2	**71.9**
Pendimethalin 38.7 CS @ 680 g *a.i.* /ha as PE *fb* pyrithiobac sodium 10 EC 75 g *a.i.* /ha + quizolofop ethyl 5 EC @ 37.5 g *a.i.* /ha at 25 DAS as PoE.	91.6	96.6	**94.1**	10.8	11.9	**11.4**	85.2	84.6	**84.9**
Weed free check	106.2	105.7	**106.0**	13.2	12.8	**13.0**	96.8	93.7	**95.3**
Unweeded control	59.9	52.2	**56.1**	6.62	6.4	**6.5**	52.9	50.9	**51.9**
S.Em±	**3.1**	**3.9**	**2.2**	**0.4**	**0.6**	**0.3**	**3.6**	**3.0**	**2.2**
C.D. at 5%	**8.9**	**11.2**	**6.3**	**1.2**	**1.7**	**1.0**	**10.6**	**8.8**	**6.4**

Table 3. Yield in eco-friendly weed management through non-chemical approaches in HDPS cotton

Treatment	2017	2018	Pooled
Mulching with black polythene	1293	1230	**1262**
Mulching with cotton stalk at 5 t /ha	1072	1063	**1068**
Mulching with paddy straw at 5 t /ha	1246	1174	**1210**
Cotton + Sunnhemp (1:1) and *in situ* mulching at 45 DAS	1340	1258	**1299**
Cotton + Cowpea (1:1) and *in situ* mulching at 45 DAS	1225	1182	**1204**
Weeding with cycle weeder at 25, 50 and 75 DAS	980	993	**986**
HW at 25 DAS and IC at 50 and 75 DAS	1069	1155	**1112**
Eucalyptus extract @ 20 % as PE *fb* IC at 50 and 75 DAS.	1173	1257	**1215**
Prosopis juliflora extract @ 20 % as PE *fb* IC at 50 and 75 DAS.	1121	1144	**1133**
Cassia tora @ 20 % as PE fb IC at 50 and 75 DAS.	1148	1093	**1120**
Parthenium extract 20 % as PE *fb* IC at 50 and 75 DAS.	1145	1114	**1130**
Pendimethalin 38.7 CS @ 680 g *a.i.* /ha as PE *fb* pyrithiobac sodium 10 EC 75 g *a.i.* /ha + quizolofop ethyl 5 EC @ 37.5 g *a.i.* /ha at 25 DAS as PoE.	1308	1239	**1274**
Weed free check	1467	1277	**1372**
Unweeded control	906	927	**917**
S.Em.±	**55**	**62**	**47**
CD at 5%	**161**	**180**	**137**

3.3 Nutrient Uptake (kg /ha) by Cotton

3.3.1 Nitrogen uptake by cotton

The combined data showed that cotton utilised much more nitrogen absorption under weed free check (106.0 kg /ha) than under other treatments. The alternative treatments include the use of herbicides such as pendimethalin 38.7 CS @ 680 g a.i. /ha as PE fb pyrithiobac sodium 10 EC @ 75 g a.i. /ha + quizolofop ethyl 5 EC @ 37.5 g a.i. /ha at 25 DAS as PoE (94.1 kg /ha), cotton + sunnhemp (1:1) and *in situ* mulching at 45 DAS (90.4 kg /ha), black polythene sheet mulch (88.8 kg /ha), in situ mulching at 45 DAS (90.4 kg /ha), hand weeding (HW) at 25 DAS, and in situ mulching (IC) at 50 and 75 DAS (88.3 kg /ha) were comparable to one another but much better than the unweeded control.

3.3.2 Phosphorus uptake by cotton

Weed-free check (13.0 kg /ha) showed significantly increased cotton phosphorus uptake compared to the other treatments. Pendimethalin 38.7 CS @ 680 g a.i. /ha as PE fb pyrithiobac sodium 10 EC @ 75 g a.i. /ha + quizolofop ethyl 5 EC @ 37.5 g a.i. /ha at 25 DAS as PoE (11.4 kg /ha), cotton + sunnhemp (1:1) and then in situ mulching at 45 DAS (10.8 kg /ha), cotton (6.5 kg /ha).

3.3.3Potassium uptake by cotton

Weed free check (95.3 kg /ha) showed a higher potassium uptake by cotton than other treatments. Pendimethalin 38.7 CS @ 680 g a.i. /ha application at 25 DAS as POE (84.9 kg /ha), cotton + sunnhemp (82.1 kg /ha) and cowpea (1:1), and then in situ mulching at 45 DAS black polythene mulch (72.3 kg /ha) and HW at 25 DAS and IC at 50 and 75 DAS (79.0 kg /ha) were comparable to each other but significantly better than unweeded control.

Treatments for weed management had a significant impact on cotton ability to absorb nutrients (N, P, and K) when compared to controls. Given that there were no weeds and no competitors, the weed free check treatment had the highest nutrient uptake. Pendimethalin @ 680 g a.i. /ha PE and pyrithiobac sodium @ 75 g a.i. /ha + quizalofop ethyl 37.5 g a.i. /ha (94.1 kg N /ha, 11.4 kg P /ha, and 84.9 kg N /ha) were discovered to be more effective than other treatments. Black polythene mulch also demonstrated higher uptake among eco-friendly methods, intercropping and subsequent in situ mulching of sunnhemp and cowpea. The crop output of dry matter, the availability of nutrients, and the concentration of nutrients in the plants all had an impact on how well the crop absorbed the major nutrients. Therefore, in these treatments, the crop was able to produce more dry matter and absorb more nutrients since there was less weed competition throughout the crop cycle [14]. The lower soil N, P, and K status under unweeded control may be attributable to higher weed populations, which would reflect more nutrient depletion by weeds in the soil, i.e. competition for applied nutrients between the weed and crop, which lowers the crop's availability of nutrients and, in turn, lowers the crop's growth, yield attributes, and yield. Lower uptake was ultimately the effect of this. Similar findings were noted by Madavi [15] (Table 2).

3.3.4 Seed cotton yield

The combined data showed that the seed cotton yield was significantly higher (1,72 kg /ha) when cotton and hemp were planted together (1:1). This was followed by in-situ mulching at 45 DAS (1299 kg /ha), pendimethalin 38.7 CS @ 680 g a.i./ha as PE fb pyrithiobac sodium 10 EC 75 g a.i./ha + quizolofop ethyl 37.5 g These methods were comparable to one another and outperformed unweeded control (917 kg /ha). Significantly less competition for nutrients between cotton plants and weeds in this treatment led to significantly higher yield, growth components, and yield qualities [16]. Black polythene mulch prevented light from reaching the weeds, which reduced the intensity of the weeds and produced the desired result [17] (Table 3).

4. CONCLUSION

In situ mulching at 45 DAS of sunnhemp or cowpea in cotton with 1:1 ratio was suitable for minimising weed competition and permitted increased DMP and nutrient uptake by the plant in HDPS cotton. The macronutrient contents in cotton crop were higher in weed free check and this was comparable to cotton + sunnhemp (1:1) or cotton + cowpea (1:1). Pre-emergence treatment of Eucalyptus extract @ 20% as PE fb IC at 50 and 75 DAS recorded considerably lower weed density, dry weight, and nutrient uptake as compared to control and was on par with other leaf extractants.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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