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Herbigation in cotton (*Gossypium* spp): Effects on weed control, soil microflora and succeeding greengram (*Vigna radiata*)

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ABSTRACT

Field experiments were conducted for two seasons (2008-09 and 2009-10) to evaluate the effects of herbigation on pre and post emergence weeds under irrigated condition in cotton (*Gossypium* spp). Application of herbicides through drip and conventional spraying were studied for pre-emergence application of single herbicide, Pendimethalin 1.5 kg/ha +hand weeding at 30 and 60 days after sowing (DAS), pre-emergence application of mixture of Pendimethalin 1.0 kg/ha+ Metolachlor 1.0 kg/ha + hand weeding at 30 and 60 DAS, herbicide rotation of pre-emergence pendimethalin 1.0 kg/ha followed by hand weeding at 30 DAS and application of metolachlor 1.0 kg/ha were compared against hand weeding thrice (20,40, and 60 DAS) and unweeded control. No significant difference was observed between herbigation and conventional spraying method on weed control efficiency in pre-emergence application (3 DAS), while herbigation was found to be effective for post emergence weed control.Herbicide rotation of pre-emergence application of pendimethalin 1.0 kg /ha followed by hand weeding and application of metolachlor 1.0 kg/ha as an early post emergence herbicide on 30 DAS resulted in the lowest dry matter production by weeds, lesser nutrient removal and on par seed cotton yield with hand weeding thrice. Significant reduction in microbial population due to weed control methods was observed initially (30 DAS), which recovered at later crop growth stages (90 DAS).It is concluded that herbicide application methods or herbicidal treatments do not affect the succeeding greengram (*Vigna radiata* L.) crop and soil microbial population.

Key words: Cotton, Herbigation, Seed cotton yield, Soil microbes, Weed control efficiency

Herbigation, an application of herbicides through irrigation water can be efficiently done through drip irrigation. Cotton (*Gossypium* spp) crop is sensitive to weed competition during initial growth stages due to its slow growth and wider spacing. The pre-emergence herbicides can manage weeds only up to 30 DAS (Nalayini and Kandasamy 2001) and controlling the late emerging weeds is really a challenge in cotton production. Application of post emergence herbicides to supplement pre-emergence treatments may give the desired season long weed control in cotton (Dadari and Kuchinda 2004). As we hardly have selective broad-spectrum post emergence weed killer for cotton, farmers perform several hand weeding and inter-cultivation operations to control weeds which adds to the cost of production. Providing timely weed control becomes difficult, in case of heavy rains, the soils become sticky and wet and trafficability is poor while in the dry soil, the surface becomes hard making inter-row cultivation difficult and also, non-availability of human labourers for weeding makes timely weed control difficult, tedious and costly affair. Repeated use of same herbicide or herbicides of same chemical class may result in development of herbicide resistance in weeds. Vargas and Wright (2005) suggested rotating herbicides with different modes of action to delay the development of resistance in weeds. Choice of herbicides for broad-spectrum weed control and at the same time delaying the development of herbicide resistance in weeds is crucial. In India, herbicides are generally sprayed using knapsac sprayers. Application of post emergence herbicides through conventional spraying is difficult near the cotton crop and hence weeds which emerge close to cotton crop escape. In the present study, we have evaluated an alternative system of herbicide application (herbigation) for control of pre and post emergence weeds in cotton along with its effects on soil microbes and succeeding pulse crop. In India, cotton crop is under drip irrigation in about 5000 ha area and there is further scope to extend this area for the judicious use of water for irrigation. Thus our present study will be useful to manage weeds under drip irrigated cotton.

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MATERIALS AND METHODS

The experimental field was located at 11° North latitude, 77° East longitude at an altitude of 426.72 m above MSL. The field trial was conducted on a vertisol under irrigated condition at Central Institute for Cotton Research Regional Station farm, Coimbatore in 2008-2009 and 2009-2010 during winter (August – February) season. After the field preparation to a fine tilth, raised beds of the size 9 m × 1.5 m were formed leaving 30 cm on all around the bed. In each bed, leaving 30 cm from the edge of bed, two sowing lines were marked at 90 cm apart. In each raised bed, one drip lateral was used for two rows of cotton. The drip lateral lines were fitted with turbo key drippers to deliver 8 lph. The turbo key drippers were fitted at 60 cm apart so as to share one dripper for two crop hills/plants. The treatments were arranged in split plot design with herbigation (through drip) and conventional spraying in the main plots with five weed control treatments in the sub plots comprising of pendimethalin 1.5 kg/ha a.i. (3 DAS) + two hand weedings at 30 and 60 DAS herbicide mixture of pendimethalin 1.0 kg/ha + metolachlor 1.0 kg/ha a.i. as pre emergence spray (3 DAS) + two hand weedings at 30, 60 DAS, herbicide rotation of pendimethalin 1.0 kg/ha as pre-emergence spray (3 DAS) followed by one hand weeding at 30 DAS to remove the emerged weeds and applying metolachlor 1.0 kg/ha (30 DAS) to target the emerging weeds by residual action up to 60 DAS and compared against unweeded control. For the drip treatment, the herbicides were applied through drip laterals and to enhance the spreading of herbicides in soil surface, wetting agent, APSA (All purpose spray adjuvant) was used at the rate of 0.3 ml per liter of spray solution.The soil of the experimental fields was low in nitrogen (157.8, 164.5 kg/ha), high in phosphorus (24.7, 26.5 kg/ha) and potassium (605.4, 645.7 kg/ha)in the first and second year of experimentation respectively with the pH of 8.5 and EC 0.28 dS/m. The extra long staple Bt cotton cultivar, RCHB 708 was used in the experiment. The cotton sowing was done at 29 and 30 of August during 2008 and 2009.The irrigation was scheduled at 0.8 ETc and applied through drip laterals for herbigated plot and as conventional irrigation for normal method. The volume of water to be given on alternate days through drip was calculated using the following formula

$$V = E_p \times K_p\ (0.7) \times K_c \times a$$

where, V, Volume of water to be given (liters) / dripper; E_p, pan evaporation (mm); K_p, pan co-efficient (0.7); K_c, crop co-efficient .For Cotton, it was 0.45, 0.75, 1.15 and 0.75 for initial (0-25 DAS), development stage (26-70 DAS), boll development (71-120 DAS) and maturity stage (121-harvest) respectively; A , area to be irrigated.

The weed control efficiency (WCE) has been worked out using the following formula.

$$WCE = \frac{\text{Dry matter of weeds in control plot} - \text{Dry matter of weeds in treated plot}}{\text{Dry matter of weeds in control plot}} \times 100$$

The recommended fertilizer dose of 120:60:60 kg of N: P_2O_5: K_2O was applied to cotton crop as NK in four equal splits at monthly interval coinciding the growth stages of squaring, peak flowering and boll development of cotton and the entire P as basal. The soil samples for microbial enumeration were collected on 28 September and 27 November of the 2008-09 cropping season. and the crop was bollworm free in both the years of experimentation..The final picking of cotton was completed in the first week of March in both the years and the bioassay crop of greengram cultivar Co-7 was sown on 11 and 13 March of 2008 and 2009 respectively immediately after the harvest of cotton.The data collected were statistically analysed and the pooled mean is presented and discussed.

Soil microbiological analyses

Rhizosphere soil samples (0-30 cm soil depth) collected from different treatment plots were serially diluted in 90 ml Ringers solution up to 10^{-4} dilution and 1 ml of aliquot was pour plated in selective media, viz. Nutrient Agar for bacteria (Allen 1959), Martin's Rose Bengal Agar for fungi (Martin 1950), Ken Knights and Munaier's Agar (Allen 1959) for actinomycetes and Buffered Yeast Agar for yeast. The plates were incubated at optimum temperature (28ºC±1ºC for bacteria and yeast; 30ºC±1ºC for fungi and actinomycetes) in triplicates. The microbial colonies appearing after the stipulated time period of incubation (3 days for bacteria and yeast; 5 days for fungi; 7 days for actinomycetes) were counted and expressed as total culturable colony forming units (Cfus)/g of the sample.

RESULTS AND DISCUSSION

Weed flora of the experimental field

The experimental field had 26 broad leaved weeds, 7 grass weeds, and one sedge weed. The broad leaved weeds were, *Abutilon indicum, Acalypha indica, Amaranthus spinosus, Amaranthus viridis, Argemone mexicana, Boerhaavia diffusa, Coccinia indica, Convolvulus arvensis, Corchoru strilocularis, Croton sparsiflorus, Datura fastuosa, Digera arvensis, Euphorbia hirta, Indigofera ennaphylla, Leucas urticefolia, Malvastrum coromandelianum, Oldenlandia umbellate, Parthenium hysterophorus, Phyllanthus maderaspatensis, Phyllanthus niruri, Portulaca oleracea, Priva leptostachya, Sonchus oleraceus, Trianthema portulacastrum, Tridax procumbens* and *Vicoa indica.* The grassy weeds, viz. *Cynodon dactylon, Dinebra arabica, Eleusine aegyptiaca, Panicum colonum, Panicum repens, Pennisetum cenchroides, Sporobolus scabrifolius* and the lone sedge weed, *Cyperus rotundus* were present in the experimental field. Among the weed species, *Trianthema*

portulacastrum was the most dominant weed flora during initial stage of cotton growth and after 60 days, grass weeds were also competing severely with cotton crop for the growth factors.

Effect of herbicide treatments on weed control in cotton

The weed dry matter production on 30 DAS was numerically lesser (12.77 g/m^2) in conventional spraying than in herbigated plot (15.15 g/ m^2). The difference might be attributed to the improper wetting of soil surface on third day of cotton sowing under herbigation. As the surface soil is very dry, there was slow wetting of soil under herbigation for the first three days. However, both methods were statistically on par.Among the weed control treatments hand weeded plot recorded the lowest dry matter. Among the herbicides, application of mixture of pendimethalin 1.0 kg / ha + metolachlor 1.0 kg/ha recorded numerically lesser weed dry matter than other herbicidal treatments, but all the herbicidal treatments were statistically on par.

The weed dry matter production at 60 DAS revealed that herbigation recorded significantreduction in weed growth (41.02 g/m ^{2}) than in conventional spraying (51.08 g/m ^{2}) and this might be due to thorough wetting of soil under herbigation since the irrigation is scheduled every alternate days under drip system, the soil is always wet and hence thorough wetting of surface soil facilitates easy spread of herbicide molecule in soil. On the otherhand, under conventional spraying, application of post emergence residual herbicides (post emergence to cotton) involves some difficulty in applying near the cotton plant unlike application before emergence and hence weeds emerge closer to the cotton plants. Also the chance of weed seed transport along with irrigation water under conventional method, as this period involves more frequency of irrigation as per the crop demand. Thus, herbigation resulted in significant reduction of dry matter accumulation by weeds (41.02 g/m^2) with corresponding reduction in depletion of N, P and K to the tune of 20.5, 17.5 and 19.7 % than conventional spraying (Table 1). The significant reduction in weeds growth under herbigation as compared to conventional spraying was reflected from reduced dry matter accumulation by weeds, reduction in depletion of nutrients by weeds and favourable micro climate to cotton crop caused the enhanced seed cotton yield of 14.3% than conventional method. Excellent weed control with site specific recommendation of metolachlor and metribuzin through herbigation has been reported by Eberlen *et al*. (2000).

Weed control treatments differed significantly for dry matter production of weeds, nutrient depletion by weeds and seed cotton yield. Among the weed control treatments, herbicide rotation of pre-emergence application of pendimethalin 1.0 kg followed by hand weeding and application of metolachlor 1.0 kg as early post emergence herbicide on 30 DAS resulted in the lowest dry matter production by weeds (13.95 g / m^2) and this might be due to efficient control of emerging weeds by the residual action of metolachlor. The same trend was recorded in depletion of nutrients by weeds. The herbicide rotation + hand weeding

Table 1 Weed DMP, weed control efficiency, nutrient depletion by weeds on 60 DAS and seed cotton yield as influenced by herbigation and weed control treatments (pooled mean)

Treatment	Weed DMP (g/m^2) 30 DAS	Weed DMP (g/m^2) 60 DAS	Total number of women labourers used for weeding/ha	WCE	Nutrients depletion by weeds (kg/ha)			Seed cotton yield (kg/ha)
					N	P	K	
Application method (M)								
Herbigation	15.15	41.02		88.4	17.33	7.05	19.22	3998
Conventional spraying	12.77	51.08		86.5	21.80	8.54	23.92	3498
CD (P=0.05)	NS	4.07			1.75	0.647	1.75	496.4
Weed control treatments (W)								
Pendimethalin 1.5 kg (pre)+ HW (30,60 DAS)	14.2	35.98	50	84.2	11.39	3.97	11.86	3949
Pendimethalin 1.0 kg + metolachlor 1.0 kg (pre) + HW (30,60 DAS)	13.7	32.73	40	85.7	9.96	4.11	10.76	4294
Pendimethalin 1.0 kg (pre) followed by HW (30 DAS), metolachlor 1.0 kg (30 DAS)	17.5	13.95	20	94.0	4.14	1.93	4.57	4669
Handweeding (20,40 and 60 DAS)	3.2	32.48	90	86.0	9.50	3.79	11.22	4821
Unweeded control	35.4	231.8			62.83	25.19	69.43	817.3
CD (P=0.05)	5.95	7.85			1.36	0.249	1.39	460
Interaction	NS	NS			NS	NS	NS	NS

Table 2 Microbial population (cfu/g of dry soil) as influenced by application methods and weed control treatments

Treatment	Microbial population (cfu × 10^4/g of dry soil)						Germination % of bioassay crop
	30 DAS			90 DAS			
	Bacteria	Fungi	Actino-mycetes	Bacteria	Fungi	Actino-mycetes	
Application method (M)							
Herbigation	39.9	7.60	13.4	71.40	12.20	23.0	88.4
Conventional spraying	45.5	6.80	18.8	71.14	12.00	22.53	86.2
CD (P=0.05)	NS	NS	NS	NS	NS	NS	5.31
Weed control treatments (W)							
Pendimethalin1.5 kg/ha (pre) + HW (30, 60 DAS)	39.2	5.0	10.85	70.7	12.65	23.15	87.5
Pendimethalin1.0 kg + metolachlor 1.0 kg/ha (pre) + HW (30, 60 DAS)	26.5	3.70	11.50	70.5	11.50	20.85	87.7
Pendimethalin 1.0 kg/ha followed by 1 HW + metolachlor 1.0 kg/ha (30 DAS)	39.2	5.15	15.50	70.0	10.15	23.30	86.8
Hand Weeding thrice (20, 40 and 60 DAS)	50.5	10.0	22.30	70.3	12.00	22.20	87.5
Unweeded control	58.0	12.20	20.35	74.9	14.15	24.30	87.02
CD (P=0.05)	13.6	3.30	9.50	NS	NS	NS	2.52
Interaction	NS	NS	NS	NS	NS	NS	NS

was on par with manual weeding thrice (20,40 and 60 DAS) for seed cotton yield and found significantly superior to rest of the treatments. Bielinski *et al.* (2008) reported that in heavy soils, application of s-metolachlor through drip lines was considered to be most effective method for weed control in tomato.

Effects of delivery methods and herbicide combinations on soil microbial population

The application methods did not influence the microbial population. While the weed control treatments influenced the microbial population on 30 DAS. Significantly lesser microbial population was recorded under all the herbicide treatments after 30 DAS (Table 2).The reduction in the microbial population might be due to toxic environment in the soil created due to herbicidal spray. However, the initial set back in microbial population was recovered over a period of time (Table 2) as the toxicity level decreased with time. The microbial population build up at 90 DAS clearly suggested that none of the herbicides or methods of application inhibited the microbial population significantly as compared to unsprayed control and hence all the herbicides and methods tried are safe to be used in cotton crop.The increase in the microbial population after 90 DAS indicates the adaptability of soil microbial population to the changing environment in the crop rhizosphere. Most studies have shown that the use of herbicides at recommended application rates does not adversely affect the microbial activity (Lupwayi *et al.* 2004, 2007). Smith (1982) reported no significant residual toxic effect to soil microbes due to application of inorganic herbicides.

Bioassay crop to assess the residual toxicity

The residual toxic effect of herbicides applied to previous crop on succeeding crop could be assessed by growing sensitive crop like pulses. The germination of bio assay crop of greengram raised immediately after the harvest of cotton was not affected by any of the herbicides tested or method of application (Table 2) hence herbigation found safe to be used in cotton based cropping system.

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