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Research Paper

Response of cotton (*Gossypium hirsutum*) to organic amendments and weed-management practices

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ABSTRACT

A field experiment was conducted during 2015–16 and 2016–17 at Department of Agronomy, TNAU, Coimbatore, Tamil Nadu to determine the effects of organic amendments and weed-control methods on weed control, yield and fibre quality of cotton (*Gossypium hirsutum* L.). Different organic amendments included (farmyard manure, vermicompost, composted poultry manure and goat manure), while weed-control methods comprised manual weeding, twin wheel hoe weeder and power-operated weeder for improvement in growth and yield of cotton. The results of pooled data indicated that, composted poultry manure along with hand-weeding twice at 20 and 45 days after sowing (DAS) recorded significantly lower weed density (27.29 No./m^2), higher weed-control efficiency (84.80%) and higher crop dry-matter production (4,637 kg/ha), sympodial branches/plant (19.74), fruiting points/plant (54.01), bolls/plant (20.87), seed-cotton yield (1,602 kg/ha) compared with the other treatments. Application of organic materials along with manual weeding significantly improved available nutrient content, soil microbial biomass carbon, decreased soil electrical conductivity in short-term, and resulted in higher cotton yield and higher soil organic matter content. These results indicated that, application of composted poultry manure in addition with hand-weeding or weeding with power-operated weeder would do more to improve soil organic matter content, increase soil organism abundance, reduce weed population and improve seed-cotton yield.

Key words **:** Cotton, Composted poultry manure, Hand-weeding, Lint yield, Power operated weeder, Weed biomass

Cotton is the most important natural fibre crop; its fibre is used throughout the world and supports 250 million peoples' livelihood. Nowadays cotton-production technology relies heavily on the use of fertilizers to supply nutrients and chemical pesticides to control insect-pests, diseases and weeds. Use of chemicals at such scale is causing a lot of hazards for human health and economics, i.e. environmental pollution, soil health, agro-ecology and poor profitability in cotton farming (Channagoudar *et al.,* 2013). This has basically prompted the demand of organically cultivated, eco-friendly or 'green' cotton. Weeds can be seen everywhere during the growth of the crop. These weeds severely compete with crops for moisture, nutrients and space, strongly disturbing the normal growth of the crop and resulting in severe yield loss and quality reduction (Ayyadurai *et al.,* 2013). Emerging weeds in cotton-production zones and their management is a major crop-production challenge across the world. Crop-weed competition for the first few weeks (4–7) after sowing has a great effect on cotton yield. Heavy weed infestations due to poor weed-management practices are estimated to reduce cotton seed yields by about 30–40% (Ali *et al.,* 2013). Organic cotton fibre is considered extremely important to Indian economy and organic cultivation is a sustainable tool, available today, to revitalize the fast-depleting agricultural lands of the country (Venugopalan *et al.,* 2011). The production of organic cotton is rather knowledge–intensive than resource intensive, thus less dependent on fossil fuels and synthetic inputs. The growing public awareness of the conventional farming methods has led to an increase in both the demand and production of organic cotton growers.

MATERIALS AND METHODS

A field experiment was conducted the Tamil Nadu Agricultural University, Coimbatore (11° N, 77° E, 426.7 m above mean sea-level) in the Western agro-climatic zone of Tamil Nadu. The nutrient status of soil at the beginning and after the experiment was low in available nitrogen (192 and 183 kg/ha), medium in available phosphorus (17.2 and 15.5 kg/ha) and high in available potassium (520 and 507

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kg/ha) respectively. The experiment was laid out in strip-plot design, replicated thrice. Treatments consisting of farmyard manure (N_1), vermicompost (N_2), composted poultry manure (N_3) and goat manure (N_4) were assigned to the main plot; whereas hand-weeding (W_1), twin wheel hoe weeder weeding (W_2), power-operated weeder weeding (W_3) and weedy check (W_4) treatments were assigned to subplot. The organic manures on equal nitrogen basis (80 N kg/ha) were applied to the respective plots as per treatment schedule (Table 1). Phosphorus and potassium were not applied separately and whatever contained in the organic manures are taken into account and fulfilled the nutrient requirement of the crop. For manual weeding treatment, 2 hand-weedings were given at 20 and 40 days after sowing (DAS). For mechanically weeded plots, 2 weedings were given at 20 and 40 DAS with twin wheel hoe weeder and power weeder between rows and the weeds present within the rows were removed manually.

Seeds of the test variety 'Suraj' were treated with cowdung slurry at 1%, a day before sowing and dried in shade. The seeds were treated with biocontrol agent *Bacillus subtilis* @ 10 g/kg of seed. Two seeds/hill were dibbled in flat beds with using the seed rate of 15 kg/ha at a spacing 75 cm × 30 cm and at a depth of 2–3 cm in the field. Five plants from each net plot area were chosen randomly and tagged. These plants were used for recording all biometric observations at different stages of crop growth. Data collected were subjected to analysis of variance. The means were separated using the least significant difference (LSD) test at 5% probability level (Gomez and Gomez, 2010).

RESULTS AND DISCUSSION

Dominant weed flora in experimental site

Weed flora of the experimental field consisted of 4 species of grassy weeds, 7 species of broad-leaf weeds and 1 species of sedge category. In general, weed infestation was higher in 2015–16 than 2016–17, especially in terms of density and dry weight of weeds. The predominant grassy weeds were: *Echinochloa frumentacea* (L) and *Cynodon dactylon* (L.) Pers. Among the broad-leaf weeds, *Trianthema portulacastrum* L., *Boerhavia diffusa* (L) and *Digeria arvensis* Forsskal. were dominant. *Cyperus rotundus* (L.) was the only sedge present. Comparing the weed species during both the years of study, grassy weed species, especially *Echinochloa frumentacea* found dominant during 2015–16 compared to second crop (2016–17). Controversially, *Trianthema portulacastrum* highly took over into second crop than first crop in terms of densities due to higher availability of weed seed bank in soil ecosystem as well as applied organic manures (Nalayini and Suveetha, 2016).

Total weed population

Different organic manures showed significant difference with respect to total weed density at all the stages of observation (Table 2). Pooled data results showed that, among the nutrient-management practices, application of composted poultry manure resulted in significantly lesser total weed density of 123.6 (No./m^2) and was comparable with 100% RDN through goat manure at 20 DAS.

A similar trend was observed at 40 and 60 DAS (73.36 and 69.36 No./m^2 respectively). Composting (recommended under organic standards) could greatly reduce the number of viable weed seeds as the temperature during composting was maintained more than 60°C for more than 3 days. Compost limits weed growth by releasing phytotoxic substances in immediate environment of weed seeds (Amanullah *et al*., 2006) as well reduces weed seed bank and competitive ability. The treatment that received farmyard manure showed higher weed density from beginning to harvesting stage (Ali *et al.,* 2013).

With respect to weed-management practices, at 20 DAS, there was no significant between the weed-control practices due to implementing scheduled treatment after recording weed population. Hand-weeding done at 20 and 40 DAS resulted in lower total weed density of 50.85 and 38.71 No./m^2 at 40 and 60 DAS, respectively, and it was closely followed by power weeder weeding at 20 and 40 DAS. Weed management either with manual or mechanical method reduced the weed stand in the earlier crop-growth stages which might have lowered the weed seed return and ultimately reduced the densities of weed species (Deshpande *et al.,* 2007). Invariably weedy check exhib-

Table 1. Nutrient content of organic manures and quantity applied during both seasons

Source of organic manures	Nutrient (%) (2015–16)			Supply RDN (80 kg/ha)	Nutrient (%) (2016–17)			Supply RDN (80 kg/ha)
	N	P	K		N	P	K	
Farmyard manure	0.5	0.2	0.5	16.0	0.6	0.2	0.5	13.11
Vermicompost	1.5	1.0	1.5	5.33	1.5	1.0	1.5	5.33
Goat manure	1.3	1.0	2.0	6.15	1.4	1.0	2.0	5.71
Comosted poultry manure	2.0	2.60	1.4	4.00	2.2	2.63	1.4	3.63

RDN, Recommended dose of nitrogen

ited the highest total weed density at all stages of observation, viz. 20, 40 and 60 DAS. Higher population of grasses, sedges and broad-leaf weeds were associated with weedy check (Nadeem *et al*., 2013).

Interaction between organic manures and weed-management practices was significant at 40 and 60 DAS. Substantially lower dry weight of total weed was recorded at 40 and 60 DAS in 100% RDN through composted poultry manure along with hand-weeding done at 20 and 40 DAS (38.2 and 27.29 No./m^2) and at 40 and 60 DAS it was comparable with 100% RDN through composted poultry manure with power weeder weeding done on 20 and 40 DAS.

Weed control efficiency

Application of 100% RDN through composted poultry manure along with hand-weeding twice at 20 and 40 DAS was taken as base to work out the weed-control efficiency, as very low weed density was recorded under this treatment in pooled data of both the years (Table 3). Comparing the various sources of organic manures on weed-control efficiency, there was much difference between the organic manures, though composted poultry manure showed higher weed-control efficiency.

Higher weed-control efficiency (74.32 and 82.66%) was noticed at 40 and 60 DAS with hand-weeding done at 20 and 40 DAS and was followed by power weeder weeding owing to greater reduction of grasses, sedges and broadleaf weeds at all the stages of crop growth, which increased the vigour and growth of cotton that resulted in better crop growth which in turn smothered the weed growth in comparison to others treatments, recording maximum weed-control efficiency (Nadeem *et al*., 2013).

Composted poultry manure along with hand-weeding twice at 20 and 40 DAS recorded higher weed-control efficiency (76.13 and 84.80% at 40 and 60 DAS respectively) followed by the treatment combination of composted poultry manure with power weeder weeding done at 20 and 40 DAS. However, at later stages, effective weed control was achieved under 2 hand-weedings or power weeder weeding in terms of reduced biomass of weeds and led to higher weed-control efficiency (Malarkodi, 2017). Lower weed-control efficiency was recorded under farmyard manure applied plot with weedy check treatment. This might be due to initial higher weed growth under farmyard manure and subsequent higher emergence of grasses, sedges and broad-leaf weeds along with weedy check.

Growth and yield of cotton

Dry-matter production:

With regard to organic manures, application of 100% RDN through composted poultry manure resulted in higher

Table 2. Effect of organic manures and weed-management practices on density of total weeds (No./m^2) in cotton (pooled data)

Treatment	20 DAS					40 DAS					60 DAS				
	W_1	W_2	W_3	W_4	Mean	W_1	W_2	W_3	W_4	Mean	W_1	W_2	W_3	W_4	Mean
N_1	13.35	13.58	13.57	13.75	13. 56	7.97	8.51	8.25	15.34	10.02	7.34	8.04	7.64	16.07	9.77
	(177.6)	(184.0)	(183.5)	(188.7)	(183.4)	(62.96)	(71.94)	(67.64)	(234.9)	(109.3)	(53.44)	(64.11)	(57.87)	(257.7)	(108.3)
N_2	12.57	12.65	12.67	12.79	12.67	7.50	7.87	7.61	14.59	9.39	6.51	7.26	7.03	15.39	9.05
	(157.5)	(159.6)	(159.9)	(163.1)	(160.0)	(55.7)	(61.51)	(57.48)	(212.5)	(96.79)	(41.94)	(52.21)	(48.99)	(236.2)	(94.84)
N_3	11.56	11.70	11.92	12.18	11.84	6.86	7.58	6.96	13.41	8.70	5.72	6.77	6.22	14.25	8.24
	(133.1)	(136.3)	(141.5)	(147.9)	(139.7)	(46.54)	(57.01)	(47.9)	(179.31)	(82.69)	(32.18)	(45.39)	(38.17)	(202.6)	(79.58)
N_4	10.84	11.18	11.08	11.45	11.14	6.22	7.24	6.63	12.66	8.19	5.27	6.60	5.38	13.39	7.66
	(117.0)	(124.4)	(122.4)	(130.6)	(123.6)	(38.2)	(51.88)	(43.48)	(159.9)	(73.36)	(27.29)	(43.02)	(28.43)	(178.7)	(69.36)
Mean	12.08	12.28	12.31	12.54	7.14	7.80	7.36	14.00	6.2 1	7.17	6.57	14.77			
	(146.3)	(151.1)	(151.8)	(157.6)	(50.85)	(60.59)	(54.13)	(196.64)	(38.71)	(51.18)	(43.36)	(218.81)			
	N	W	N at W	W at N		N	W	N at W	W at N		N	W	N at W	W at N	
SEm±	0.13	0.05	0.14	0.16		0.08	0.11	0.15	0.14		0.02	0.06	0.11	0.10	
CD(P=0.05)	0.41	NS	NS	NS		0.17	0.24	0.45	0.44		0.05	0.13	0.27	0.25	

Figures in parentheses are mean of original values; Data subjected to square-root transformation; DAS, days after sowing
Details of treatments are given under Materials and Methods

total dry-matter production of 601, 1520, 2602 and 4056 kg/ha at 30, 60, 90 and 120 DAS, respectively, and it was followed by goat manure. Increased plant height and more number of enlarged leaves increased the photosyntates, which in turn enhanced higher biomass productions under composted poultry manure (Fig. 1). The continuous slow release of nutrients might have enabled the leaf-area duration to extend thereby providing an opportunity for plants to increase the photosynthetic rate which could have led to higher accumulation of dry-matter as reported by Amanullah *et al*. (2006).

Marked variation in the dry-matter of cotton crop was noticed at all the stages due to different weed management methods. Hand-weeding twice on 20 and 40 DAS registered higher dry matter production (617; 1,579; 2,684 and 4,221 kg/ha at 30, 60, 90 and 120 DAS, respectively) and was comparable with power weeder weeding on 20 and 40 DAS which might be due to lesser weed competition in this treatment which allowed crop plants to grow better with proper utilization of available resources without competition by weeds. Nalayini and Suveetha (2016) reported that, higher dry matter production in hand weeded plots can be attributed to reduction in competition by weeds which in turn increased growth and development of the crop.

The treatment combination of composted poultry manure with 2 hand weedings or power weeder weeding had the best effect in reducing fresh and dry broad-leaf, grassy and total weeds at 20 and 40 DAS which might have led to an increase in the crop-growth attributes of plant height, leaf-area index (LAI) and dry matter at all the stages of observation. Application of composted poultry manure could have reduced the weed germination in the early growth stages and hand-weeding at 20 and 40 DAS might have reduced the weed growth and hence was better than the other treatments combinations (Reddy *et al.*, 2007).

Yield attributes of cotton

The entire yield attributes, viz. sympodial branches/plant (17.98), bolls/plant (17.40) and fruiting points/plant (46.65) were positively influenced by 100% RDN through composted poultry manure followed by goat manure application during both years (Table 4). Higher availability of nutrients from organic manures for plant development and boll formation, gradual transformation and mineralization of organics, solubilization of water-insoluble P compounds by organic acids released during decomposition of organics resulting in greater P availability to crop coupled with higher native K availability might have played a key role in ensuring superior yield attributes (Tewolde *et al.,* 2009).

Among the weed-management techniques, hand-weeding at 20 and 40 DAS improved the yield characters of cotton followed by 2 power weeder weedings. This might be owing to reduction in crop-weed competition which favoured the growth of crop that encouraged better availability of nutrients and better translocation of photosynthates from source to sink and higher accumulation of photosynthates in the boll-formation stage (Kulvir and Rathore, 2015).

Weedy check produced less number of sympodial branches, boll/plant and boll weight in cotton. This might be due higher weed density during the critical period of crop-weed competition in cotton which might have resulted in interrupted absorption and utilization of radiation energy leading to lower photosynthetic rate finally leading to less accumulation of dry matter (Deshpande *et al.,* 2006)

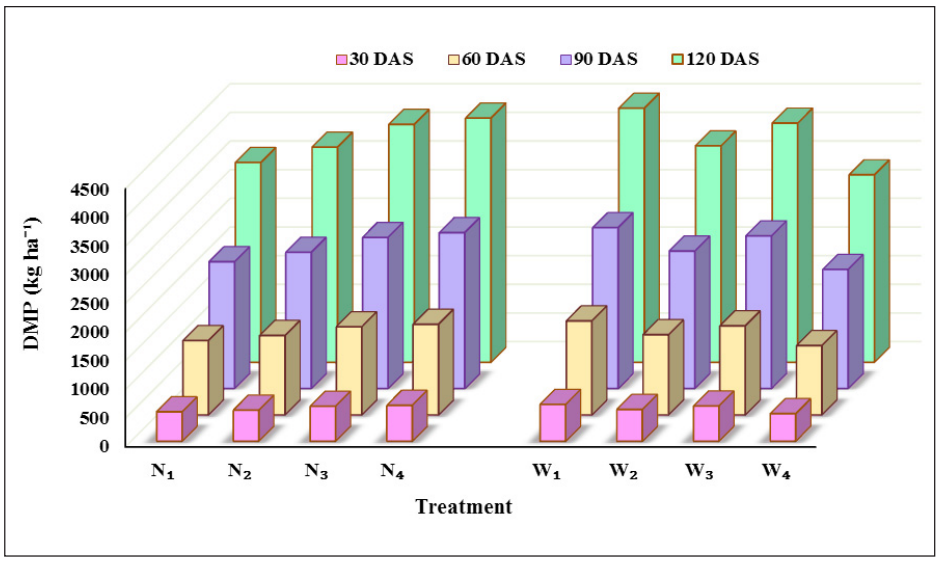

Fig. 1. Effect of organic manures and weed management practices on dry matter production (kg/ha) of cotton (Details of treatments are given under Materials and Methods)

Table 3. Effect of organic manures and weed management practices on weed control efficiency (%) of cotton (Pooled data)

Treatment	20 DAS					40 DAS					60 DAS				
	W_1	W_2	W_3	W_4	Mean	W_1	W_2	W_3	W_4	Mean	W_1	W_2	W_3	W_4	Mean
N_1	5.81	2.39	2.66	0.00	2.72	73.27	69.44	71.27	0.00	53.50	79.33	75.17	77.61	0.00	58.03
N_2	3.47	2.14	1.95	0.00	1.89	73.81	71.08	73.02	0.00	54.48	82.30	77.95	79.32	0.00	59.89
N_3	9.80	7.83	4.29	0.00	5.48	74.06	68.23	73.35	0.00	53.91	84.20	77.64	81.22	0.00	60.77
N_4	10.10	4.76	6.07	0.00	5.23	76.13	67.58	72.81	0.00	54.13	84.80	75.98	84.19	0.00	61.24
Mean	7.30	4.28	3.74	0.00		74.32	69.08	72.61	0.00		82.66	76.69	80.59	0.00	
	N	W	N at W	W at N		N	W	N at W	W at N		N	W	N at W	W at N	
SEm±	0.59	0.54	1.87	1.88		0.36	0.44	1.08	1.07		0.15	0.75	0.76	0.66	
CD(P=0.05)	1.89	1.72	5.03	4.97		1.15	1.42	2.94	3.00		0.47	2.38	1.97	1.58	

DAS, Days after sowing
Details of treatments are given under Materials and Methods

Table 4. Effect of organic manures and weed-management practices on yield attributes of cotton (pooled data)

Treatment	Sympodial branches/plant					Fruiting points/plant					Bolls/plant				
	W_1	W_2	W_3	W_4	Mean	W_1	W_2	W_3	W_4	Mean	W_1	W_2	W_3	W_4	Mean
N_1	16.77	10.66	15.36	9.85	13.16	41.49	35.13	41.40	29.80	36.95	15.17	12.35	15.02	9.90	13.11
N_2	18.53	13.64	17.35	10.42	14.98	52.29	34.76	45.70	33.69	41.61	19.28	12.55	16.78	11.27	14.97
N_3	19.29	16.94	19.02	13.83	17.27	51.66	41.86	42.85	34.27	42.66	19.40	15.58	16.19	11.72	15.72
N_4	19.74	17.31	19.55	15.32	17.98	54.01	48.46	49.85	34.31	46.65	20.87	17.62	19.17	11.95	17.40
Mean	18.58	14.64	17.82	12.35		49.86	40.05	44.95	33.02		18.68	14.53	16.79	11.21	
	N	W	N at W	W at N		N	W	N at W	W at N		N	W	N at W	W at N	
SEm±	0.36	0.29	0.56	0.51		0.68	0.53	1.22	1.10		0.45	0.41	0.67	0.60	
CD (P=0.05)	0.89	0.80	1.25	1.12		1.68	1.59	2.71	2.38		1.10	1.04	1.51	1.32	

DAS, days after sowing
Details of treatments are given under Materials and Methods

Seed-cotton yield

Seed-cotton yield was influenced by organic manures and weed-management practices as well as their interaction during both the years (Table 5). Pooled data revealed that, among the organic manures, significantly higher seed-cotton yield (1,391 kg/ha) was recorded under 100% RDN through composted poultry manure followed by 100% RDN through goat-manure supply the nutrients in soluble form for a quiet longer period by not allowing the entire soluble form into solution, to come in contact with soil and plant roots can absorb more nutrients leading to better yield (Ahmed *et al*., 2019). However, lower yield (1,163 kg/ha) was observed under 100% RDN through FYM.

The response of cotton to weed-management practices was much substantial. Hand-weeding at 20 and 40 DAS resulted in higher seed cotton yield (1,484 kg/ha) followed by power weeder weeding at 20 and 40 DAS. It might be owing to the decreased weed competition and minimized nutrient removal by weeds thereby provided a competition free environment for the crop for better growth and development (Gnanavel and Babu, 2008).

Table 5. Effect of organic manures and weed management practices on seed yield of cotton

Treatment	Pooled data (2015–16 and 2016–17)				
	W_1	W_2	W_3	W_4	Mean
N_1	1,424	1,035	1,272	922	1,163
N_2	1,439	1,164	1,316	957	1,219
N_3	1,472	1,417	1,517	984	1,347
N_4	1,602	1,430	1,506	1,026	1,391
Mean	1,484	1,261	1,402	972	
	N	W	N at W	W at N	
SEm±	36	24	65	59	
CD (P=0.05)	88	58	143	127	

The interaction effect between organic manures and weed-management practices significantly influenced the seed cotton yield. In general, application of 100% RDN through composted poultry manure with hand-weeding on 20 and 40 DAS recorded higher seed-cotton yield (1602 kg/ha) than the other treatment combinations followed by composted poultry manure (100% RDN) along with 2 power weeding at 20 and 40 DAS and both were comparable. Application of 100% RDN farmyard manure with weedy check recorded lower yield due to higher weed density and in turn recorded the least nutrient uptake by cotton which might be due to maximum utilization of resources by weeds (Kulvir and Rathore, 2015).

Thus, the results revealed that 100% RDN through composted poultry manure along with hand-weeding or power weeder weeding at 20 and 40 DAS recorded lesser weed density, higher growth and improved root growth and activity which improved the remobilization of photosynthates from vegetative organs to reproductive parts and ultimately enhanced the yield attributes and yield of cotton.

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Research Paper

Bio-efficacy of glufosinate ammonium on weed control and yield of cotton (*Gossypium hirsutum*)

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ABSTRACT

A field experiment was carried out at Instructional farm, Mohanpur, West Bengal, India during the rainy season of 2016 and 2017 to study the bio-efficacy of glufosinate ammonium 13.5% SL (15% w/v) herbicide on weed control, growth and yield of Bt-cotton hybrid (*Gossypium hirsutum* L.). The experiment was conducted in 3 times replicated randomized block design (RBD) comprising 7 weed-control treatments, viz. 4 doses of glufosinate ammonium 13.5% SL (15% W/V) @ 300, 375, 450 and 525 g/ha, paraquat dichloride 24% SL @ 500 g/ha, hand-weeding (weed-free control) and weedy control. The weed-free treatment by frequent hand-weeding showed maximum growth parameters, yield attributes and yield of cotton. Among the herbicidal treatments, the post-emergence application of glufosinate ammonium 13.5% SL (15% W/V) @ 525 g/ha was found to be the alternative of hand-weeding in respect to weed-control efficiency, growth and yield of cotton. This treatment also realized the highest net return (₹ 41,689/ha) and benefit: cost ratio (2.11), followed by glufosinate ammonium 13.5% SL (15% W/V) @ 450 g/ha.

***Key words*:** Bio-efficacy, Cotton, Glufosinate ammonium, Hand-weeding, Weeds, Yield

Cotton (*Gossypium* sp.) is one of the major sources of raw material in textile industries and India is on top in world's area and production of cotton cultivation with an estimate of 12.24 million ha and 34.025 million bales in 2018–19 (Cotton Association of India, 2019). Growth of textile industries in India is constantly demanding more and more production of this fibre crop. Although the conventional varieties of cotton are being successfully replaced by hybrid ones in order to address the demand, its productivity is comparatively lower (506.07 kg/ha in 2017–18) in India as compared to world's average (775 kg/ha) (Cotton Association of India, 2019). Of the various reasons for lower yield, weed problem is the major one.

Weed problem is now becoming a serious concern for cotton-growers the world. These unwanted plants steal the resources which otherwise could have been utilized by the crop. Weeds also harbour many harmful disease-causing pathogens and insects that further affect fibre yield and quality of cotton. On an average, the yield loss incurred by weeds in cotton ranges from 40 to 85% (Nandagavi and Halikatti, 2016). So, the adoption of suitable weed-management practices is the key to address such yield losses and quality improvement of cotton. Hand-weeding has historically been the common and preferred practice of the farmers owing to its assurance of high success. But the major constraint associated with it is high involvement of labour and thus, makes it an uneconomical approach. Further, the agro-climatic situation in rainy (*kharif*) season not always permits the manual measures of weed control. With the invention of the cost-effective herbicides, farmers are now able to overcome the issue where labour shortage is a major crux. The timely application of herbicides at various formulation and doses may be a quick, economical and efficient alternative of hand-weeding to kill the weeds and thus plays a role in upliftment of crop productivity. Glufosinate ammonium is one such herbicide which is now being successfully used in many crops including cotton. The herbicidal property of this synthetic metaphrase of phosphinothricin (by-product of bialaphos from *Streptomyces viridochromogenes* and *Streptomyces hygroscopicus)* was first reported by Droge-Laser *et al.* (1994). This contact herbicide is already known to control wide spectrum of weeds (Chompoo and Pornprom, 2008). In order to obtain the best result from this herbicide, the doses should be

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