RESEARCH ARTICLE

Management of Weed Seed Bank Using Nanoparticles in Combination with Pendimethalin and Hydrogen Peroxide in Irrigated Blackgram (*Vigna mungo* L.)

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ABSTRACT

Field experiments were carried at Agricultural College and Research Institute, Madurai, Tamil Nadu Agricultural University, Tamil Nadu, during *kharif* and *rabi* seasons of 2017 - 2018, to study the effect of nanoparticles in combination with pendimethalin and hydrogen peroxide on weeds and blackgram crop. The experiments were laid out in randomized block design with twelve treatments and replicated thrice using blackgram MDU 1 as a test variety. Among the weed control treatments, application of H_2O_2 followed by Pendimethalin + Ag nanoparticles recorded lower weed index, total weed dry weight, total weed density and with higher weed control efficiency and yield of black gram in both the seasons. It was comparable with the application of pendimethalin (0.75 kg a.i. ha^{-1}) + hand weeding at 35 DAS.

Keywords: *Blackgram, Hydrogen peroxide, Zinc oxide, Silver Nanoparticles, Pendimethalin and Weed management.*

INTRODUCTION

India is the largest producer and consumer of pulses in the world accounting for 33.6 per cent of the world area and 24 per cent of the world production (Pramanik and Bera., 2012). Among the pulse crops, blackgram is an important legume crop cultivated worldwide in tropical and subtropical regions. In India, it occupies an area of 4.48 m ha with a production of 2.83 million tonnes and average productivity of 641 kg ha^{-1}. Even though the cultivated area is higher, the productivity of pulses in India is low. Among the various factors responsible for the lower yield of blackgram, heavy weed infestation is one of the predominant reasons (Rao *et al.,* 2010). The crop is not a very good competitor against the weeds and therefore weed control initiatives are essential to ensure proper crop growth, particularly in the early growth period. Further the enlargement of weed seed bank is considered as a serious problem for the subsequent crops in the cropping sequence. Exhausting the weed seed bank reduces the crop weed competition and improves the growth and yield of any crops. Several pre and post emergence herbicides were used for controlling weeds in pulses. Amidst the situation, the newly emerging science the nano-technological approach throws some light to check effectively the enlargement of weed seed bank by exhausting weed seeds from soil and preventing addition of seeds in the current season (Gu *et al.,* 2009). Hydrogen peroxide is a biocide commonly used for sterilizing soil borne pathogens (Linley *et al.,* 2012). An attempt has been made to study the effect of pendimethalin in combination with nanoparticles and hydrogen peroxide on the weed seed bank and weed control in black gram.

MATERIALS AND METHODS

Field experiments were conducted at the Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai, Tamil Nadu, during *kharif* and *rabi* seasons of 2017-2018. The site was located at $9^0.54'$ N latitude and $78^0.80'$ E longitude at an altitude of 147 m above mean sea level. The region falls under southern zone of Tamil Nadu.

The experimental site was situated in semi-arid tropical region. The mean annual rainfall accounts to 856 mm, of which 39.8 per cent is normally distributed during south west monsoon, 42 per cent during north east monsoon, 2.1 per cent during Winter and 16.2 per cent during summer. The soil of the experimental field was sandy clay loam in texture. The fertility status was low in available nitrogen (231 kg ha^{-1}), medium in available

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phosphorus (16.4 kg ha^{-1}), medium in available potassium (294.8 kg ha^{-1}), organic carbon (0.34 %), pH (1:2 soil water suspension) (7.1).

The experiment was laid out in randomized block design, replicated thrice using MDU 1 blackgram as the test variety with the following treatments H_2O_2 30 ml m^{-2} alone (T_1) and in combination with Ag Nanoparticles @ 500 ppm m^{-2} (T_2), ZnO Nanoparticles @ 500 ppm m^{-2} (T_3), Pre-emergence application of pendimethalin @ 0.75 kg a.i ha^{-1} alone (T_4), H_2O_2 *fb* pendimethalin @ 0.75 kg a.i ha^{-1} (T_5). Treatments $T_{6,}$ T_7 consisted of pendimethalin + Ag Nanoparticles and ZnO Nanoparticles, respectively. T_8 and T_9 consisted of H_2O_2 *fb* pendimethalin + Ag Nanoparticles or ZnO Nanoparticles, respectively. $T_{10,}$ T_{11} and T_{12} comprised of pendimethalin + hand weeding @ 35 DAS, weed free check and unweeded check, respectively.

Hydrogen peroxide (H_2O_2) was applied in soil one day before sowing. The recommended dose of fertilizer *viz.,* 25:50:25 kg N, P_2O_5 and K_2O ha^{-1} was applied as basal to all the plots. The N was applied in the form of urea (46 % N), P was applied in the form of single super phosphate (16 % P_2O_5) and K was applied in the form of Muriate of Potash (60 % K_2O). For improving the growth and flower initiation foliar spray of 2% DAP applied at 35 DAS. Silver nanoparticles were synthesized by soluble starch method (Saware *et al*., 2015) and the zinc oxide (ZnO) nanoparticles were synthesized in the laboratory through chemical routes (Talam *et al*., 2012). The synthesized nanoparticles were characterized using scanning electron microscope (SEM) and the images were taken in 24,000X magnification and 15 to 30 KV using FEI ESEM Model "QUANTA 250". The observation on total weed density, total weed dry weight and weed control efficiency were recorded at 20, 50 DAS and at harvest stage. Weed index and yield of black gram were recorded after harvest of the crop. The data on the weeds were statistically analyzed as suggested by (Gomez and Gomez, 1984). The data on weed density and weed dry weight were subjected to square root transformation $\sqrt{(x + 0.5)}$ before analysis. The treatment differences were worked out at five per cent probability level.

RESULTS AND DISCUSSION

Weed flora of the experimental field

The weed flora observed in the experimental field consists of grasses, sedges and broad leaved weeds (Table 1). Sedges and broad leaved weeds were the predominant weeds observed throughout the crop growth period. The weed flora consists of three species of grasses, two species of sedges and six species of broad leaved weeds. The major grasses were *Echinochloa colonum, Echinochola crusgalli* and *Cynodon dactylon*. Among the grasses *Cynodon dactylon* is the dominant grass weed. *Cyperus rotundus* and *Cyperus iria* were the predominant sedges. In sedges *Cyperus rotundus* is the key sedge weeds in the experimental trial. The important broad leaved weeds were *Commelina benghalensis, Cleome viscosa, Convolvulus arvensis, Trianthema portulacastrum, Euphorbia hirta, Phyllanthus niruri* and *Eclipta alba*. Among the broad leaved weeds *Trianthema portulacastrum* is the major weed species in the field.

Table 1. Weed flora of the experimental field during cropping season

Botanical name	Common name	Life span	Family
A. Grasses			
1. *Echinochloa colonum* (L.) Link	Jungle rice	Annual	Gramineae
2. *Echinochola crusgalli* (L.) Beav	Barnyard grass	Annual	Gramineae
3. *Cynodon dactylon* (L.) Pers	Bermuda grass	Perennial	Gramineae
B. Sedges			
1. *Cyperus rotundus* (L.)	Purple nut sedge	Perennial	Cyperaceae
2. *Cyperus iria* (L.)	Rice flat sedge	Perennial	Cyperaceae
C. Broad leaved weeds			
1. *Commelina benghalensis* (L.)	Day flower	Perennial	Commlinaceae
2. *Cleome viscosa* (L.)	Wild mustard	Annual	Compositae
3. *Convolvulus arvensis* (L.)	Field bind weed	Perennial	Convolvulaceae
4. *Trianthema portulacastrum* (L.)	Horse pursiane	Annual	Leguminosae
5. *Eclipta alba* (L.)	False daisy	Annual	Asteraceae
6. *Phyllanthus niruri* (L.)	Keela nelli	Annual	Euphorbiaceae

Total weed density

The total weed density (Table 2) was significantly influenced by the different weed control treatments in irrigated blackgram. Among the treatments, application of pendimethalin + hand weeding at 35 DAS recorded the lower weed density of 95.62, 95.31 and 146.76 weeds m^{-2} at 20, 50 DAS and at harvest in *kharif* and 84.66, 109.07 and 130.04 weeds m^{-2} at 20, 50 DAS and at harvest in *rabi,* respectively. This might be due to the activity of pendimethalin herbicide during early stages and the hand weeding reduced the weed growth throughout the cropping season. Followed by this treatment, application of H_2O_2 *fb* pendimethalin + Ag Nps recorded the lower weed density of 102.83, 137.54 and 178.59 weeds m^{-2} at 20, 50 DAS and at harvest in *kharif* and 90.93, 123.49 and 158.74 weeds m^{-2} at 20, 50 DAS and at harvest in *rabi*, respectively. The populations of broad leaved weeds were effectively reduced by the application of pendimethalin. There was a significant reduction in the flowering of *Cyperus rotundus* and total sedge population. This may be due to the action of silver nanoparticles. The applied nanoparticles might have entered in to the weed system and degraded the phenol and starch present in the tubers. Degradation of phenols, the germination inhibitor, by the nanoparticles, induce the buds present in the tuber to burst open, simultaneously degradation of the food reserve in the tubers which supplies energy for the young germinating buds, make it starve and leads to death of the new plants (Viji and Chinnamuthu, 2015).

Table 2. Effect of nanoparticles in combination with pendimethalin and hydrogen peroxide on total weed density and total weed dry weight

Treatment No.	Total weed density (no. of weeds m^{-2})						Total weed dry weight (kg ha^{-1})					
	Kharif			*Rabi*			*Kharif*			*Rabi*		
	20 DAS	50 DAS	At harvest	20 DAS	50 DAS	At harvest	20 DAS	50 DAS	At harvest	20 DAS	50 DAS	At harvest
T_1	151.95 (12.35)	196.69 (14.04)	276.10 (16.63)	135.07 (11.64)	175.45 (13.26)	245.75 (15.69)	532.40 (23.08)	793.54 (28.18)	1207.13 (34.75)	466.00 (21.60)	725.41 (26.94)	1089.84 (33.02)
T_2	139.54 (11.830	189.03 (13.77)	226.31 (15.06)	124.00 (11.16)	168.55 (13.00)	201.98 (14.23)	487.83 (22.10)	758.00 (27.54)	1014.77 (31.86)	426.29 (20.66)	692.86 (26.33)	916.62 (30.28)
T_3	144.43 (12.04)	193.75 (13.94)	250.13 (15.83)	128.29 (11.35)	172.78 (13.16)	222.92 (14.95)	506.59 (22.52)	781.37 (27.96)	1106.80 (33.28)	442.53 (21.05)	714.21 (26.73)	997.80 (31.60)
T_4	127.49 (11.31)	187.87 (13.72)	264.50 (16.28)	112.68 (10.64)	166.79 (12.93)	234.32 (15.32)	405.56 (20.15)	693.52 (26.34)	1071.75 (32.75)	350.72 (18.74)	636.08 (25.23)	965.02 (31.07)
T_5	118.34 (10.90)	159.37 (12.64)	195.90 (14.01)	104.93 (10.27)	141.62 (11.92)	174.13 (13.21)	375.39 (19.39)	588.80 (24.28)	806.24 (28.40)	326.50 (18.08)	540.11 (23.25)	728.92 (27.00)
T_6	115.37 (10.76)	156.44 (12.53)	193.57 (13.93)	102.07 (10.13)	139.27 (11.82)	173.00 (13.17)	369.32 (19.23)	584.90 (24.19)	803.99 (28.36)	319.45 (17.89)	536.62 (23.18)	630.80 (25.13)
T_7	118.31 (10.90)	159.86 (12.66)	202.01 (14.23)	104.62 (10.25)	142.21 (11.95)	180.40 (13.45)	377.85 (19.45)	596.17 (24.43)	837.00 (28.94)	326.10 (18.07)	546.94 (23.40)	658.82 (25.68)
T_8	102.83 (10.17)	137.54 (11.75)	178.59 (13.38)	90.93 (9.56)	123.49 (11.14)	158.74 (12.62)	326.91 (18.09)	511.74 (22.63)	736.91 (27.16)	282.03 (16.81)	474.10 (21.79)	665.59 (25.81)
T_9	110.73 (10.55)	147.94 (12.18)	194.04 (13.95)	97.85 (9.92)	133.56 (11.58)	172.40 (13.15)	350.63 (18.74)	548.71 (23.44)	815.32 (28.56)	302.41 (17.40)	510.63 (22.61)	719.93 (26.84)
T_{10}	95.62 (9.80)	95.31 (9.79)	146.76 (12.14)	84.66 (9.23)	109.07 (10.47)	130.04 (11.43)	306.67 (17.53)	374.00 (19.35)	595.33 (24.41)	264.96 (16.29)	428.02 (20.70)	550.29 (23.47)
T_{11}	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
T_{12}	186.80 (13.69)	241.88 (15.57)	361.04 (19.01)	166.58 (12.93)	216.02 (14.71)	321.34 (17.94)	669.16 (25.88)	978.29 (31.29)	1570.23 (39.63)	588.34 (24.27)	895.50 (29.93)	1417.08 (37.65)
SEd	0.21	0.24	0.29	0.19	0.23	0.27	0.39	0.47	0.60	0.36	0.44	0.56
CD(P = 0.05)	0.43	0.47	0.58	0.39	0.45	0.56	0.78	0.95	1.19	0.73	0.90	1.15

Invariably the highest weed dry weight was recorded in control plot with the weed dry weight of 186.8, 241.88 and 361.04 weeds m^{-2} at 20, 50 DAS and at harvest in *kharif* and 166.58, 216.02 and 321.34 weeds m^{-2} at 20, 50 DAS and at harvest in *rabi*, respectively. This might be due to the weeds germinated along with the crop in the unweeded plot, grew vigorously and competed for natural resources with blackgram throughout the crop (Adpawar *et al*., 2011).

Total weed dry weight

The total weed dry weight (Table 2) was significantly influenced by the different weed control treatments in irrigated blackgram. Among the treatments application of pendimethalin + hand weeding at 35 DAS recorded the lower weed dry weight of 306.67, 374 and 595.33 kg ha^{-1} at 20, 50 DAS and at harvest in *kharif* and 264.96, 428.02 and 550.29 kg ha^{-1} at 20, 50 DAS and at harvest in *rabi*. This might be due to the control of weeds during early stage by the pre-emergence application of pendimethalin which prevented emergence of monocot and grassy weeds by inhibiting root and shoot growth. While the late emerging weeds were controlled by the hand weeding resulting in the reduction of weed dry weight. This was in accordance with the findings of Mishra *et al*. (2004) and Agila and Chinnamuthu (2017).

A comparable effect on weeds was also observed with the application of H_2O_2 *fb* pendimethalin + Ag Nps which recorded the lower weed dry weight of 326.91, 511.74 and 736.91 kg ha^{-1} at 20, 50 DAS and at harvest in *kharif* and 282.03, 474.1 and 665.59 kg ha^{-1} at 20, 50 DAS and at harvest in *rabi* season. Application of hydrogen peroxide might have reduced the germination and viability of weed seeds in turn reduced the total dry weight of weeds. Further combined application of nanoparticles with herbicide might have reduced the emergence as well as killing of emerged weeds in general very particular to the sedge weeds. This might be due to the degradation of starch present in the tubers of *Cyperus rotundus* by the nanoparticle results in the death of emerged sedges for want of food by germinating young plants. Similar results were reported by Viji *et al.,* (2016) and Chinnamuthu *et al.,* (2017).

The highest weed dry weight of 669.16, 978.29 and 1570.23 kg ha^{-1} at 20, 50 DAS and at harvest in *kharif* and 588.3, 895.5 and 1417.08 kg ha^{-1} at 20, 50 DAS and at harvest in *rabi* season respectively was recorded with the unweeded check. It may be due the undisturbed weed growth during the entire crop growth period. The results corroborate with the findings of (Raj *et al*., 2012).

Table 3. Effect of nanoparticles in combination with pendimethalin and hydrogen peroxide on weed control efficiency and weed index

T. No	*Weed control efficiency*						*Weed Index (%)*	
	Kharif			*Rabi*				
	20 DAS	50 DAS	At harvest	20 DAS	50 DAS	At harvest	*Kharif*	*Rabi*
T_1	18.7	18.7	23.5	18.9	18.8	23.5	54.6	54.4
T_2	25.3	21.8	37.3	25.6	22.0	37.1	48.4	49.1
T_3	22.7	19.9	30.7	23.0	20.0	30.6	53.0	52.0
T_4	31.8	22.3	26.7	32.4	22.8	27.1	41.7	42.4
T_5	36.6	34.1	45.7	37.0	34.4	45.8	28.7	28.9
T_6	38.2	35.3	46.4	38.7	35.5	46.2	31.9	31.2
T_7	36.7	33.9	44.0	37.2	34.2	43.9	34.3	34.8
T_8	45.0	43.1	50.5	45.4	42.8	50.6	14.5	15.1
T_9	40.7	38.8	46.3	41.3	38.2	46.3	21.5	21.8
T_{10}	48.8	60.6	59.4	49.2	49.5	59.5	7.3	7.3
T_{11}	100.0	100.0	100.0	100.0	100.0	100.0	0.0	0.0
T_{12}	0.0	0.0	0.0	0.0	0.0	0.0	62.1	61.4

*Data not statistically analysed

Weed control efficiency

The weed control efficiency (Table 3) is one of the important indices, which throws light on the effect of treatment on the management of weeds. Greater the efficiency, better is the treatment effect. Among the herbicide treatments pre-emergence application of pendimethalin at 0.75 kg a.i ha^{-1} 3 DAS *fb* HW on 35 DAS recorded the higher WCE of 48.8, 60.6 and 59.4 at 20, 40 DAS and at harvest respectively in *kharif* and 49.2, 49.5 and 59.5 at 20, 40 DAS and at harvest in *rabi* respectively. The combined effect of pendimethalin and hand weeding at 35 DAS resulted in remarkably lower weed population and ultimately less dry weight of weeds.

Application of H_2O_2 *fb* pendimethalin + Ag Nps recorded higher WCE followed by (45, 43.1 and 50.5 at 20, 50 DAS and at harvest in *kharif* and 45.4, 42.8 and 50.6 at 20, 50 DAS and at harvest in *rabi* season respectively). This might be due to the strong oxidizing capacity of H_2O_2 that results in oxidative stress that causes cellular damage and death of seeds. This in turn reduces the weed seed germination which directly reduces the weed population. This coincides with the findings of Wojtyla *et al*., 2016. Further combined application of silver nanoparticles with pendimethalin might have reduced the emergence in addition to killing of emerged weeds results in lower weed population and dry weight of weeds.

Weed index

The highest weed index (Table 3) of 62.1 and 61.4 in *kharif* and *rabi* season respectively were recorded in the control plot which indicates the level of competition between the crop and weed for inputs. The higher weed index might be due to decline in growth and yield components of pulses under increased pressure of weed competition for space, light, nutrient (Shaikh *et al*., 2010).

In the present study, application of pendimethalin + hand weeding at 35 DAS was the best treatment as it was resulted in lower weed index of 7.3 in both seasons. The next best treatment was the application of H_2O_2 *fb* pendimethalin + Ag Nps with 14.5 per cent and 15.1 per cent in *kharif* and *rabi* season, respectively. This might be due to the application of hydrogen peroxide which reduces the weed seed germination and the combined application of pendimethalin and silver nanoparticles which reduces the weed population. This decreases the crop weed competition and directly increases the yield components which results in lower weed index.

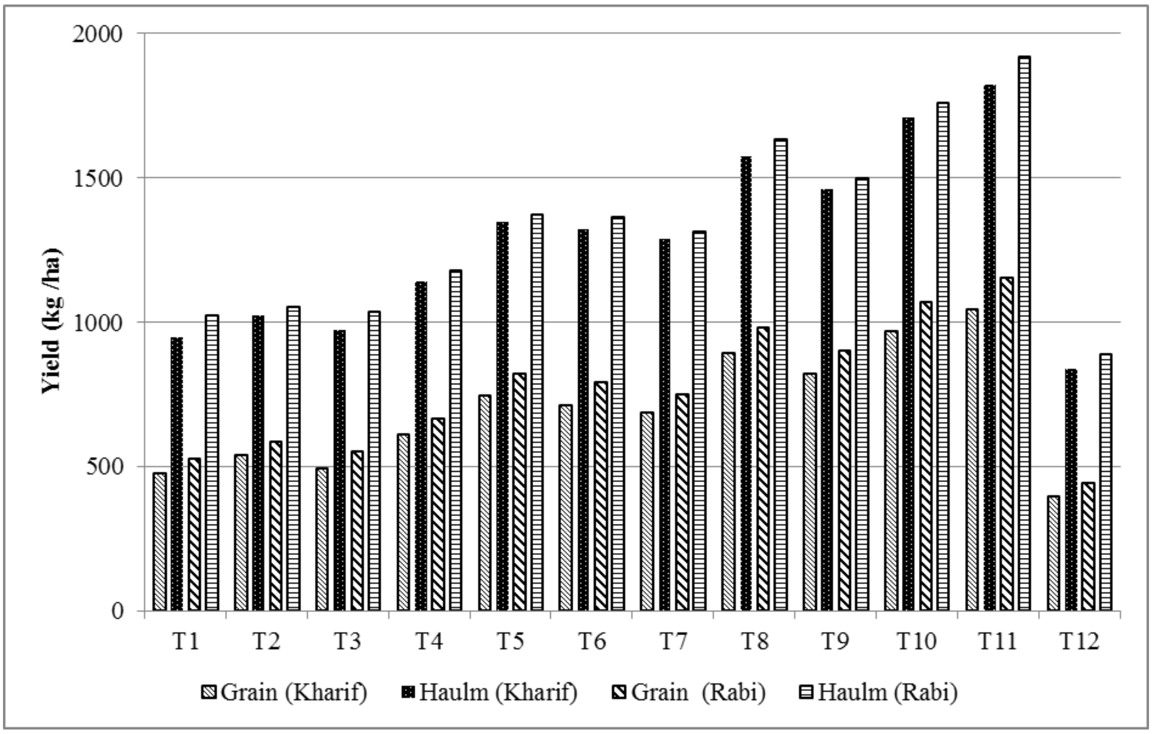

Figure 1. Effect of nanoparticles in combination with pendimethalin and hydrogen peroxide on grain and haulm yield (kg ha^{-1}) of blackgram

Grain and haulm yield

Among the herbicide treatments, the pre-emergence application of pendimethalin + HW on 35 DAS recorded the highest grain yield of 970 and 1070 kg ha^{-1}and haulm yield of 1710 and 1760 kg ha^{-1} in both the seasons. This might be due to the better season long control of all categories of weeds. The next best treatment was application of H_2O_2 *fb* pendimethalin + Ag Nps with grain yield of 894 and 980 kg ha^{-1}and haulm yield of 1576 and 1634 kg ha^{-1} in both the seasons. The unweeded check showed the real depiction of the aggressive nature of weeds on growth of irrigated blackgram. The lowest grain and haulm yield (Fig.1) were recorded in control plot. This might be due to the severe competition between crop and weed for different resources. The crops compete with weeds for the resources available, led to deficiency of nutrients resulted in reduced dry matter accumulation of crop. Similar finding was reported earlier by Raman and Krishnamoorthy (2005) and Raj *et a*l. (2012).

CONCLUSION

From the study, it could be concluded that under irrigated blackgram, application of pre-emergence herbicide pendimethalin in combination with silver nanoparticles and hydrogen peroxide effectively checked incidence of weeds which consequently may lead to, reduction in the enlargement of future soil weed seed bank.

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