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Studies on bio-efficacy and phytotoxicity of different formulation of 2, 4-D amine 50% SL in maize

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Abstract
The field trial was conducted during *Kharif* season of 2012 at RRS, New Alluvial Zone, Gayeshpur, BCKV, WB to reveal the bio-efficacy and phytotoxicity of 2,4-D Amine 50% SL in maize. The experiment comprising of nine treatments and laid out in randomized block design with replicated thrice. Application of 2,4-D amine 50% SL 2.0 kg a.i. ha^{-1} and of 2,4-D amine 50% SL1.0 kg a.i. ha^{-1} have resulted in significantly effective weed control followed by Atrazine 50 % WP 0.25 kg a.i. ha^{-1} and contributed in significantly high grain yield through these said treatments which were statistically comparable to hand weeding twice. Even up to 2.0 kg a.i. ha^{-1} of 2, 4-D amine 50% SL application there was found no phytotoxicity in maize. So, this treatment can be a good option for *Kharif* maize in medium land condition under sub-humid and sub-tropical condition of West Bengal.

Keywords: Bio-efficacy, phytotoxicity, maize, yield, 2, 4-D Amine 50% SL, correlation

Introduction
Maize *(Zea mays* L.) is one of the most versatile crops grown throughout the tropical as well as temperate regions of the world.It is the 3rd major food-grain crop after rice and wheat in India. Maize is known as 'Queen of Cereals' because of its high production potential and wider adaptability (Kumar *et al*., 2017) [4]. In India, it is cultivated on an area of 8.69 million ha with a production of 21.81 million tonnes and the productivity of 2509 kg/ha contributing nearly 9.0 per cent of the total food-grains production in the country (Anonymous, 2016) [1], while in West Bengal the area, production and productivity were 156 thousand hectare, 720 thousand tones and 4615 kg ha^{-1} respectively in the year 2015-16. Among the factors which adversely impact the productivity of maize crop, weed infestation is the most harmful one but less noticeable. The growth rate of maize especially during early stages is rather slow which helps weeds to offer effective competition in their favour. Among the factors responsible for low yields in maize, severe infestation by weeds due to wider row spacing coupled with frequent rains in rainy season inflicting huge yield losses upto 68.9% (Walia *et al*., 2007) [8] and 28-100% (Patel *et al*., 2006) [7]. However, Dogan *et al*. (2006) [3] reported that weeds reduced the corn yield by 43% when allowed to compete with crop from sowing to harvest. The magnitude of weed-related losses depends on the type and density of a particular weed species, its time of emergence, and the duration of the interference. Hence, the eradication of weeds from the crop growing areas is urgent concern for obtaining maximum returns. The various methods for eradication of weeds are hoeing, weeding, tillage, harrowing, crop rotation, biological and chemical controls. But time consuming and costly labour-intensive traditional methods have made the use of herbicides popular among Indian farmers. Many researchers working on weed management in maize opined that herbicide may be considered to be a viable alternative then hand weeding. Identification of new herbicides is vital and urgently needed to reduce the possibility of evolution of resistant biotype of weeds and getting higher maize yield. 2,4-D amine is such an exigent selective herbicide in maize field which kills many grassy and broadleaf weeds. 2, 4-D is a systemic herbicide that is absorbed through foliage and roots and is translocated to actively growing areas within the plant. In this circumstances, standardization and evaluation of 2,4-D amine is crucial for getting higher maize productivity and recovery over and again. Therefore, the present trial was conducted to test the bio efficacy and phytotoxicity of this herbicide molecule.

Materials and methods
The experiment was carried out during winter season of 2012 at Regional Research Station, New Alluvial Zone, Gayeshpur under Bidhan Chandra Krishi Viswavidyalaya, Mohanpur,

Nadia, West Bengal (22º05′ N latitude and 88º32′E longitude, 9.75m above mean sea level) to study the bio-efficacy and phytotoxicity of 2, 4-D Amine50% SL in maize in medium land under sub-humid and sub-tropical condition of West Bengal.Soil at the experimental site (0-15cm depth) was loamy in texture containing 52.57% sand, 26.3% silt and 21.12% clay with 6.58 pH and 0.54% organic carbon (OC). Available N, P_2O_5 and K_2O contents were 194.2, 47.5 and 198.1 kg/ha, respectively. Meteorological data during the cropping season revealed that maximum and minimum temperature fluctuated between 33.67 and 19.34°C in crop growth period 2012. Relative humidity prevailed between 98.1 and 50.5% in *kharif* 2012. The rainfall during the experimental period 108 mm. The trial was laid down in randomized block design with three replications and nine treatments comprising of five different doses of 2,4-D Amine 50% SL (Nufarm) applied at 0.25, 0.50, 0.75, 1.0 and 2.0 kg a.i. ha^{-1}, 2,4-D Amine58% SL (Commercial) with dose 0.50kg a.i. ha^{-1}, Atrazine50% WP with dose of 0.25 kg a.i. ha^{-1}, twice hand weeding at 20 days after sowing and 40 days after sowing were tried and check as unweeded control. The seeds of maize variety 'BN-111' were sown @ 60 kg ha^{-1} in 50 cm apart rows and 15 cm plant to plant at a depth of 5-6 cm below the soil.The gross size of plot was 5.0 m × 4.0 m = 20 m^2. All the herbicides were applied as solution in water at the rate of 500 litres/ha. The herbicide solutions were sprayed uniformly in the experimental plots as per treatments with the help of knapsack sprayer fitted with flat fan nozzle type. For counting of weed population and weed biomass, quadrate area of 0.5 m x 0.5 m was specified in every plot. Total weed population was measured as the number of weeds per unit area at 20, 40 and 60 days after sowing from the quadrates according to the weed species in situ. The observation on visual crop toxicity was done on 7, 14 and 21 days after herbicide application (DAHA). For taking weed dry matter, the destructed weed samples were first washed in clean tap water, then sun-dried and hot-air oven-dried for 48 hours at 70°C and weighed. Along with these, effect of different treatments on population of broad leaf weeds, on population of sedges and grasses, weed control efficiency (WCE) were measured.

Weed Control Efficiency (%) $WCE = \frac{WDM_c - WDM_t}{WDM_c} \times 100$

where, WDM_c = Weed dry weight in control plot & WDM_t = Weed dry weight in treated plot. On the other hand, outcomes of treatments in the grain yield, straw yield and harvest index were recorded.

Result and discussion

Effect on weed density

The field of experiment was utterly infested with diversified weed flora consisting of both dicots and monocots. It was observed that the population of broad leaf weed, grassy weed and sedge varied significantly due to weed control treatments (Table 1). The population of broad leaf weed (1.33, 0.3 and 1.7 no. m^{-2} respectively), sedge weed (0, 57, 0.18 and 0.9no. m^{-2}respectively) and grassy weed (4.4, 6.33 and 1.6 no. m^{-2} respectively) populations was lower under hand weeding twice at 20, 40 and 60 DAS. Among the herbicides, 2, 4-D amine 50% SL 2.0 kg a.i. ha^{-1} recorded least weed population at 20, 40 and 60 DAP and followed by 2, 4-D amine 50% SL 1.0 kg a.i. ha^{-1}.The total weed density was significantly reduced in the herbicide treatments. The data on weed count has revealed that2, 4-D amine 50% SL2.0 kg a.i. ha^{-1} has resulted in effective control of all type of weeds and has recorded least weed count at 20, 40 and 60 DAS and remained on par among themselves and superior to the other treatments except hand weeding twice. 2,4-D amine 50% SL 2.0 kg a.i. ha^{-1} was at par with 2,4-D amine 50% SL 1.0 kg a.i. ha^{-1} in controlling the total weed population. The unweeded control treatment recorded the highest weed count at all the observations with the pre dominance of grasses followed by broad leaf weeds and sedges respectively.These consequences are in conformity with the research findings of Biswas *et al*. 2017 [2] where it was revealed that higher dose of 2,4-D amine 50% SL has resulted in effective control of all type of weeds and has recorded least weed population at 20, 40 and 60 DAS and remained on par among themselves and superior to the other treatments except hand weeding.

Effect on weed dry matter and weed control efficiency

The dry matter production of weeds was recorded at 20, 40 and 60 DAS (Table 2). Significant differences in DMP were observed among the treatments at all the stages. At 20, 40 and 60 DAS, the lowest DMP of 39.00, 48.00, 3.10gm m^{-2} was recorded in hand weeded plot, followed by 2,4-D amine 50 % SL 2.0 kg a.i. ha^{-1} and 2,4-D amine 50 % SL 1.0 kg a.i. ha^{-1}. Consequent to the lower density of weeds observed in Hand weeding twice followed by 2,4-D amine 50% SL 2.0 kg a.i. ha^{-1} and 2,4-D amine 50% SL 1.0 kg a.i. ha^{-1}. The weed dry weight was recorded least in the aforesaid treatments. The weed dry weight in the aforesaid treatments remained on par among themselves and remain significantly superior to the other treatments at all the stages especially that the standard treatments viz., 2, 4-D amine 58% SL (Commercial) 0.5 kg a.i. ha^{-1} and Atrazine 50 % WP 0.25 kg a.i. ha^{-1}.

The indices weed control efficiency derived from the weed dry weight which disclosed the result that amongst all the treatment combinations (Table 2), the maximum value of weed control efficiency was achieved for hand weeding twice of 47.30, 42.17, 94.63 % during 20, 40 and 60 DAS, respectively. This was followed by 2,4-D amine 50% SL 2.0 kg a.i. ha^{-1} (41.89, 28.92, 80.52 % at 20, 40 and 60 DAS, respectively) and 2,4-D amine 50% SL 1.0 kg a.i. ha^{-1} (40.54, 26.39, 80.00 %at 20, 40 and 60 DAS respectively). The weed control efficiency of the aforesaid treatments remained comparable with each other and better than other treatments. The lowest WCE was recorded in unweeded control plot. Higher the dose of 2,4-D amine 50% SL greater was the weed control efficiency (WCE). Researchers and Scientists in different years have also proven that WCE reflects the effectiveness of applied weed management treatments in securing yield against weed competition.

Phytotoxicity

The observation on visual crop toxicity was done on 7, 14 and 21 days after herbicide application (DAHA). The visual crop toxicity symptoms like leaf injury, vein clearing, epinasty, hyponasty, scorching and necrosis were observed. There were no crop Phytotoxicity symptoms among the different treatments as well as at the highest dose of 2,4-D amine 50% SL 2.0 kg a.i. ha^{-1}.

Effect on yield and harvest index

Land productivity in terms of grain yield varied significantly among treatment (Table 3). Hand weeding twice recorded the highest grain yield of 5.16 t ha^{-1} which was at par with 2,4-D amine 50% SL 1.0 kg a.i. ha^{-1} (3.79 t ha^{-1}), 2,4-D amine 50%

SL 0.75 kg a.i. ha^{-1} (3.63 t ha^{-1}). This was followed by 2,4-D amine 50% SL 2.0 kg a.i. ha^{-1} (3.49 t ha^{-1}). Similar to grain yield, stover yield was also influenced due to different weed management practices. Among the treatments Hand weeding twice recorded the highest stover yield of 4.78 t ha^{-1} which was at par with 2,4-D amine 50% SL 1.0 kg a.i. ha^{-1} (4.50 t ha^{-1}), 2,4-D amine 50% SL 0.5 kg a.i. ha^{-1} (4.44 t ha^{-1}). This was followed by 2,4-D amine 50% SL 2.0 kg a.i. ha^{-1} (4.44 t ha^{-1}). These results are similar to the findings of Kundu *et al*., (2018) [5].

Correlation and regression analysis

The weed density and dry matter had highly significant negative correlation with the yield of maize (Table 4 and Fig. 1*a*, *b*). It implies that yield attributes and yield components of maize decreased with proportional increase in weed interference and vice-versa. Similar negative correlation between weeds and crop was reported by Mondal *et al*. (2019) [6], who stated that higher weed density and biomass caused significant reductions in yield attributes which in turn reduced the crop yield significantly.

From the present study, it may be inferred that the complex weed flora observed in maize can be effectively managed through application of 2,4-D amine 50 % SL 2.0 kg a.i. ha^{-1}. This would lead to better weed control with improved crop growth and grain yield of maize. These said treatments which were statistically comparable to hand weeding twice and another treatment i.e. 2,4-D amine 50% SL 1.0 kg a.i. ha^{-1}.

Table 1: Effect of treatments on density of different weeds (No.m^{-2}) in maize

T. No.	Treatment	Dose a.i. kg ha^{-1}	Broadleaved			Sedges			Grasses			Total weed population		
			20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
T_1	2, 4-D amine 50% SL (Nufarm)	0.25	5.23	2.17	3.9	2.73	1.26	3.8	9.97	6.5	3.6	17.09	8.97	10.02
T_2	2, 4-D amine 50% SL (Nufarm)	0.5	2.4	0.5	3.1	1.31	0.96	3.12	9.4	5.43	2.9	14.82	8.2	9.51
T_3	2, 4-D amine 50% SL (Nufarm)	0.75	2.36	0.5	3.3	1.43	0.6	2.91	7.16	5.3	2.93	12.03	7.1	9.43
T_4	2, 4-D amine 50% SL (Nufarm)	1	2.13	0.3	2.63	1.16	0.47	2	6.6	2.3	2.1	9.5	5.42	7.7
T_5	2, 4-D amine 50% SL (Nufarm)	2	1.43	0.3	2	0.57	0.28	2	5.9	2	2.1	8.6	3.86	6.73
T_6	2, 4-D amine 58% SL (Commercial)	0. 50	3.83	0.6	3.6	1.56	1.26	3.60	9.73	6.2	3.3	16.36	10.28	9.8
T_7	Atrazine 50% WP	0.25	2.33	0.4	3	1.2	0.56	2.6	6.86	4.36	2.5	9.75	6.08	8.4
T_8	Hand weeding (Twice)	-	1.33	0.3	1.7	0.57	0.18	0.9	4.4	6.33	1.6	8.3	3.56	4.2
T_9	Unweeded control	-	7.9	4.6	8	3.36	1.3	13.5	11.83	9.7	10.2	18.42	11.29	31.7
	SE (d)		0.13	0.1	0.16	0.04	0.03	0.13	0.25	0.20	0.17	0.47	0.44	0.32
	CD (P= 0.05)		0.38	0.2	0.43	0.12	0.09	0.37	0.75	0.5	0.49	1.39	1.32	0.92

Table 2: Effect of treatments on total weed dry matter production (g m^{-2}) and Weed control efficiency (%) in maize

T. No.	Treatment	Dose a.i. kg ha^{-1}	Weed dry matter production (g m^{-2})			Weed control efficiency (%)			Phytotoxicity observation		
			20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS	7 DAHA	14 DAHA	21 DAHA
T_1	2, 4-D amine 50% SL (Nufarm)	0.25	65	80	14.45	12.16	3.61	74.98	0	0	0
T_2	2, 4-D amine 50% SL (Nufarm)	0.5	58	74	12.45	21.62	10.84	78.44	0	0	0
T_3	2, 4-D amine 50% SL (Nufarm)	0.75	58	73	13.45	21.62	12.05	76.71	0	0	0
T_4	2, 4-D amine 50% SL (Nufarm)	1	44	61.1	11.55	40.54	26.39	80	0	0	0
T_5	2, 4-D amine 50% SL (Nufarm)	2	43	59	11.25	41.89	28.92	80.52	0	0	0
T_6	2, 4-D amine 58% SL (Commercial)	0. 50	61	77	13.85	18.92	7.23	76.71	0	0	0
T_7	Atrazine 50% WP	0.25	50	69	12.26	32.43	16.87	78.77	0	0	0
T_8	Hand weeding (Twice)	-	39	48	3.1	47.3	42.17	94.63	0	0	0
T_9	Unweeded control	-	74	83	57.75	0	0	0	0	0	0
	SE (d)		2.47	4.73	2.61	-	-	-	-	-	-
	CD (P= 0.05)		6.51	14.26	7.65	-	-	-	-	-	-

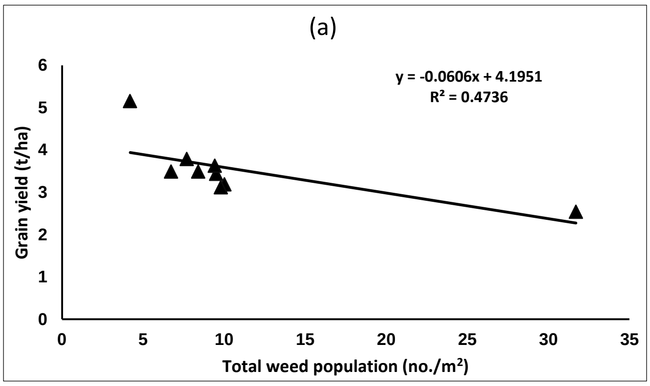
Table 3: Effect of treatments on yield of maize (t ha^{-1})

T. No.	Treatment	Dose a.i. kg ha^{-1}	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest Index (%)
T_1	2, 4-D amine 50% SL (Nufarm)	0.25	3.19	3.72	46.16
T_2	2, 4-D amine 50% SL (Nufarm)	0.5	3.44	4.17	45.20
T_3	2, 4-D amine 50% SL (Nufarm)	0.75	3.63	4.44	44.98
T_4	2, 4-D amine 50% SL (Nufarm)	1	3.79	4.5	45.71
T_5	2, 4-D amine 50% SL (Nufarm)	2	3.49	4.44	44.01
T_6	2, 4-D amine 58% SL (Commercial)	0. 50	3.12	3.74	45.48
T_7	Atrazine 50% WP	0.25	3.49	4.22	45.26
T_8	Hand weeding (Twice)	-	5.16	4.78	51.91
T_9	Unweeded control	-	2.54	2.72	48.28
	SE (d)		0.41	0.43	-
	CD (P= 0.05)		1.1	1.19	-

Table 4: Pearson's correlation matrix among the weed density and dry weight at 60 days after sowing and yield

Parameters	Weed density (no./m^2)	Weed dry weight (g/m^2)	Grain yield (t/ha)	Stover yield (t/ha)
Weed density (no./m^2)	1			
Weed dry weight (g/m^2)	0.997**	1		
Grain yield (t/ha)	-0.688*	-0.692*	1	
Stover yield (t/ha)	-0.910**	-0.898**	0.820**	1

Value followed by * and ** denote correlation is significant at 0.05 and 0.01 level respectively (2-tailed).



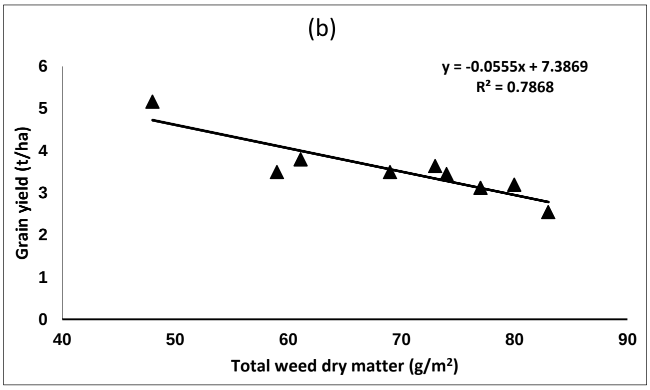


Fig 1: Relationship between (*a*) grain yield and weed density at 60 DAS; (*b*) grain yield and weed dry matter at 40 DAS;

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