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Investigation of The Potential Effects of Salicylic Acid in Enhancing the Herbicidal Activity of Stomp Herbicide for Controlling Weeds and Improving the Yield of Mung Bean.

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ABSTRACT

Natural products from plants have increasingly become an encouraging destination for many researchers in order to mitigate the environmental pollution risks arising from the growing use of synthetic herbicides. The current work is devoted to study the potential effects of the integrated application of salicylic acid and stomp herbicide on controlling weeds and increasing grain yield in mung bean. Salicylic acid was used alone[twice; 30 and 45 days after sowing (DAS)] at 500 and 1000 ppm and in combination with stomp (once, 30 DAS) at 50 and 75% of the field recommended dose (1.0 l/feddan; fed = 4200 m^2).The recommended dose (full dose) of stomp, hand weeding twice (30 and 45 DAS) and a weedy check treatment were included for comparison. All salicylic acid/stomp herbicide treatments were applied during summer season. Treatment that has received salicylic acid (500 ppm)/stomp (75% of the recommended dose) combination provided greater weed control and grainyield than other combinations. A 89.29% increase in grain yield was recorded in this regard as compared with the unweeded control treatment. However, the highest mung bean grain yield was related to the application of hand weeding twice and stomp at the full dose. Integration of salicylic acid with reduced herbicide doses is certainly an innovative approach to improve herbicidal activity and application characteristics. It is further promising from multiple health and environmental perspectives.

Keywords: Reduced herbicide doses, salicylic acid, plant-derived compounds, natural herbicides, mung bean, weeds

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INTRODUCTION

Weeds are a problem of considerable importance causing many negative economic, ecological and social impacts [1-3]. Because of their pioneering and dynamic nature, weeds will continue to be a serious threat to crop production and secure food and nutrition around the world [4-5]. The ability of weeds to shift in response to management practices and environmental conditions puts an extra burden on the controlling process [6]. Controlling weeds is mandatory to avoid considerable crop losses and ensure acceptable production levels.

With world orientation towards using non-chemical weed management methods for environmental and health reasons, there has been a growing concern amongst researchers on allelopathy phenomenon as an option for the safe and successful weed control [7-8]. Chemical-based weed management (herbicides) is sufficiently effective but can have a profound adverse impact on nearly every aspect of our lives and the natural ecosystems, since many of the negative consequences of pollution are assumed by synthetic pesticides [9]. Manual weeding is favorable to avoid pollution and herbicide resistance [10]. Yet, the high labor costs are discouraging; manual weed control is generally labor intensive and therefore a costly operation [11]. Thus searching for alternatives is necessary to overcome many of these problems and to ensure rational crop yield.

A great deal of research has been done over the last four decades on allelopathy phenomenon with the main aim of using in controlling weeds [12-13].Researchers have covered a large area of plant-plant interactions that take place below- and aboveground[14]. Allelochemicals have been studied more extensively involving their expected role as future bioherbicides [15-17]. Recently, allelopathy has been considered within a broader scope of research including sustainable agriculture, environment conservation, intercropping systems, vegetation structure, soil properties and nutrient availability as it causes a number of environmental and economic problems that seriously affect the whole agricultural process [15;18].

Inclusion of allelopathy in the agricultural process can be done effectively via using allelopathic crops (cover crops, mulching and crude plant extracts) or through using allelochemicals that even could be used directly as herbicides or as templates for new synthetic herbicides [19-21]. A special focus has been forward to using allelopathic extracts and allelochemicals in combination with herbicides to reduce standard herbicides dose [22-25]. Recent research referes that natural phytotoxins offer unparallel source of structural diversity with the opportunity of developingboth directly-used natural chemicals and synthetic herbicides with new target sites that may not be targeted by any herbicide developed by other strategy [26].Thus allelopathy provides attractive chance for safe and effective weed management.

Mung bean (*Vigna radiata*) is an important legume crop widely spread in many parts of the world. It is grown as a short duration crop between principle crops in subtropical zones of the world including India, Bangladesh, Malaysia, Pakistan and China [27]. Mung bean is one of the distinctive features of Asian agriculture, where it is commonly cultivated for its edible seeds and sprouts [28]. It is a cheap, rich source of carbohydrates (51%), easily digestible protein (24–26%), minerals (4%) and vitamin (3%) that makes it a stable legume in many diets and nutrients around the world especially in developing countries where it replaces scarce animal protein there [29]. There has been a common opinion that mung bean is native to India and transformed from it to both developing and development countries. During the last four decades mung bean has been shifted from a marginal, semi-domesticated crop to a major legume crop in many countries of Asia [30]. The total area under mung bean cultivation in the world is currently estimated at around 6 m ha with an average yield of 0.4 – 0.68 t/ha [31-33]. Approximately 90% of the world production is mainly situated in Asia [34].

Although mung bean is produced in many African countries including Egypt where it is recently introduced, it is still not a major crop or a major food item there [35-36]. Adaption to the totality of Egyptian conditions alongside improving yield characteristics has been studied extensively [37-38].

The present study was initiated to investigate the potential impact of salicylic acid in increasing the herbicidal efficiency of stomp herbicide in controlling weeds and increasing yield productivity of mung bean.

MATERIALS AND METHODS

A field experiment was conducted during summer season at the Agricultural Experimental Station of the National Research Centre at Shalakan Distric, Kalubia Governorate, Egypt. The aim of this study was to investigate the potential impact of salicylic acid in increasing the herbicidal efficiency of stomp herbicide in controlling weeds and increasing productivity of mung bean. The soil texture of experimental site was clay (14.4 % sand, 32.6 % silt and 53.0 % clay) with pH of 7.88; 2.11% organic matter; 1.95 % $CaCo_3$; EC 1.29 mmhos/cm^2 and having 41.8, 19.8 and 225 ppm available N, P and K, respectively in the upper 30 cm layer of the soil.

Cultivation method: The soil was ploughed twice using a chisel plow and divided into 10.5 m^2 experimental units. A uniform basal dressing of phosphate fertilizer as calcium super phosphate 15.5% P_2O_5 at the rate of 150 kg/fed was applied during seed-bed preparation. Mung bean seeds (*Vigna radiata* Var. Kawmy-1) were inoculated with the specific strain of rhizobium (*Bradyrhizobium* spp.) and immediately sown broadcasting in the experimental units at rate of 25 kg/fed on the first week of May, 2014 season using dry method of sowing. A starter dose of N at rate of 15 kg/fed was applied before the first irrigation (15 days from sowing) in the form of ammonium nitrate (33.50% N). Other agronomic practices were applied according to the recommendations of Ministry of Agriculture, Egypt.

Treatments: The study included the following treatments:

T_1: Unweeded
T_2: Hand hoeing twice (30 and 45 days after sowing; DAS)
T_3: Stomp® 330 E alone [(Pendimethalin 330 g/l, BASAF Co.; 1.0 l/fed (recommended dose)]
T_4: salicylic acid alone (500 ppm; 30 and 45 DAS)
T_5: T4 + 50% of the recommended dose of stomp
T_6: T4 + 75% of the recommended dose of stomp
T_7: salicylic acid alone (1000 ppm; 30 and 45 DAS)
T_8: T7 + 50% of the recommended dose of stomp
T_9: T7 + 75% of the recommended dose of stomp

All salicylic acid/stomp herbicide treatments were applied post emergence using a knapsack sprayer fitted with appropriate nozzle. Only salicylic acid (at both concentrations) was applied twice, other than that was sprayed once at 30 DAS when weeds were 3-5 leaves. The treatments were allocated in a randomized complete block design, each with four replicates.

Data recorded: Mung bean samples of ten plants were taken randomly from each plot (65 DAS) to determine dry weight/plant (g). Weeds were sampled at the same time from one randomly selected spot (1 m^2) in each plot and the dry weight (g) was determined. Dry weight was estimated after drying at a constant temperature of 70 °C for 48 hrs. At harvest (90 DAS) ten plants from two central rows from each plot were taken randomly to estimate plant height (cm), pods no./plant, pods weight/plant (g), seed no./pod, seed weight (g/plant) as well as 100-seed weight (g). The whole plot was harvested once and threshed to determine seed, straw and biological yields (ton/fed) as well as harvest index (%) and crop index (%).

Statistical analysis: Data were analyzed using ANOVA table and LSD test at 5% probability for the difference between means [39].

RESULTS

Response of mung bean and associated weeds to field-applied stomp either alone (at recommended dose) or in combination with salicylic acid has been investigated. The stomp herbicide as full recommended dose and its combinations with salicylic acid significantly affected (to various degrees) mung bean growth and accompanying weeds (dry weight biomass) as compared with the unweeded control treatment (Table 1, Figure; 1).

Applying salicylic acid alone (twice) at 500 and 1000 ppm showed the lowest effect in decreasing (16.67 and 12.5%, resp.) weeds growth. A stronger effect, however, was obtained on increasing (84.61 and 65.04%, resp.) mung bean growth due to these treatments. Integration of salicylic acid with reduced doses of stomp showed good response at both weed and crop growth levels (Figure 1). Even though weed growth was significantly negatively affected by salicylic acid/stomp combinations, there were no much significant variations were noted between the different combinations on increasing crop growth. As compared with the control treatment, the salicylic acid/stomp mixtures caused 84.6 - 97.0% increase in mung bean growth. On weeds growth, significant variations were noted as affected by salicylic acid concentration. Pronounced reductions between 37.50% and 66.67% in weeds growth (dry weight biomass) were estimated in comparison with unweeded control treatment (Table 1).

Given the overall results hand weeding twice and stomp alone at 1.0 l/fed (*e.g.*, recommended dose) with 110.05 - 117.22% increase in crop growth and 70.83 - 74.38% reductions in weeds growth (dry weight biomass) were significantly the best, either compared with unweeded control treatment or other combined salicylic acid/herbicide treatments (Table 1).

The influence of salicylic acid/stomp combinations on yield and its components are illustrated in tables (2, 3 and 4). The tables reflected similar trend as that produced in vegetative growth stage. Maximum plant height, no. of branches/plant, no. and weight of pods/plant, seed weight/plant, 100-seed weight and total grain yield (ton/fed) were obtained with hand weeding twice and the full dose of stomp herbicide. No-treatment significant differences existed on no. of seeds/pod (Table 2). Foliar application of stomp (alone) at the full dose increased yield components by 3.26%to 158.16% and final yield of the crop by 100% in comparison with the unweeded control treatment. Hand weeding twice achieved the highest grain yields in this regard (125%) with relatively higher values on yield components (5.89 to 198.71% increments) (Tables 3 and 4).

Applying salicylic acid in combination with the reduced doses of stomp was generally more effective than applying it alone at both concentrations (500 and 1000 ppm). Salicylic acid (500 ppm)/stomp (50 % of the recommended dose) combination resulted in increasing yield components in a range between 6.27 and 198.71% and grain yield by 73.21% as compared with the unweeded control treatment. The mixture containing the same dose rate of salicylic acid (500 ppm) and 75% of the recommended dose of the herbicide was stronger in effect as 3.26 – 112.56% and 89.29% increments were recorded in this regard for yield components and total grain yield of the crop, respectively(Tables 3 and 4). The highest dose of salicylic acid (1000 ppm) in combination with the same reported doses of stomp was less efficient. A 50% increase in grain yield was reported with the highest herbicide dose versus 28.57% with the lowest dose as compared with the unweeded control treatment (Table 4).

Table (1): Influence of exogenous application of salicylic acid and/or reduced doses of stomp herbicide on mung bean and weed growth (65 DAS).

	Character	Mung bean		Weed	
	*Weed control treatment	Dry wt. (g/plant)	Increasing % of control	Dry wt. (g m²)	Reduction % of control
T1	Unweeded	15.33	…	480.00	…
T2	Hand hoeing twice (30 & 45 DAS)	33.30	117.22	123.00	-74.38
T3	Chemical control (Stomp 1.0 L/fed)	32.20	110.05	140.00	-70.83
T4	Spraying salicylic acid (500 ppm), twice (30 & 45 DAS)	28.30	84.61	400.00	-16.67
T5	Salicylic acid (500 ppm) + 50% recommended dose of Stomp	30.00	95.69	290.00	-39.58
T6	Salicylic acid (500 ppm) + 75% recommended dose of Stomp	30.20	97.00	160.00	-66.67
T7	Spraying Salicylic acid (1000 ppm) twice (30 & 45 DAS)	25.30	65.04	420.00	-12.50
T8	Salicylic acid (1000 ppm) + 50% recommended dose of Stomp	28.30	84.61	300.00	-37.50
T9	Salicylic acid (1000 ppm)+ 75% recommended dose of Stomp	28.30	84.61	180.00	-62.50
	F test	***		***	
	$LSD_{5\%}$	7.84		64.39	
	CV%	16.87		13.37	

CV, Coefficient of variation

All salicylic acid/stomp combinations were applied once (30 DAS)

Table (2): Influence of exogenous application of salicylic acid and/or reduced doses of stomp herbicide on mung bean yield components.

Character / *Weed control treatment	Mung bean yield components at harvest						
	Plant ht. (cm)	Branches (no. plant $^{-1}$)	Pods (no. plant $^{-1}$)	Pods (g plant $^{-1}$)	Seeds (g plant $^{-1}$)	Seeds (no. pod $^{-1}$)	100-seed wt. (g)
T1	117.93	1.80	12.20	30.33	3.53	12.59	3.80
T2	145.60	3.20	29.60	90.60	10.19	13.33	4.37
T3	139.53	3.20	22.77	78.30	9.14	13.00	4.25
T4	130.80	2.40	16.80	40.10	5.10	13.00	4.19
T5	134.27	3.00	20.20	57.33	6.20	13.38	4.22
T6	135.60	3.00	19.40	64.47	7.14	13.00	4.25
T7	122.53	2.37	15.63	37.10	4.74	13.00	4.17
T8	130.40	3.00	17.80	43.50	4.87	13.34	4.19
T9	131.20	3.00	18.77	45.40	6.00	12.69	4.21
F test	***	***	***	***	***	ns	***
LSD $_{5\%}$	**2.4**	**0.15**	**1.52**	**3.54**	**0.15**	**ns**	**0.22**
CV%	**1.05**	**3.2**	**4.63**	**3.8**	**1.35**	**3.98**	**3.06**

CV, Coefficient of variation,
*Explanations including conditions of application are as in table (1).

Table (3): Influence of exogenous application of salicylic acid and/or reduced doses of stomp herbicide on mung bean yield components.

Character / *Weed control treatment	Increasing (%) of control						
	Plant ht. (cm)	Branches (no. plant $^{-1}$)	Pods (no. plant $^{-1}$)	Pods (g plant $^{-1}$)	Seeds (g plant $^{-1}$)	Seeds (no. pod $^{-1}$)	100-seed wt. (g)
T1	--	--	--	--	--	--	--
T2	23.46	77.78	142.62	198.71	5.89	188.67	15.00
T3	18.32	77.78	86.64	158.16	3.26	158.92	11.84
T4	10.91	33.33	37.70	32.21	3.26	44.48	10.26
T5	13.86	66.67	65.57	89.02	6.27	75.64	11.05
T6	14.98	66.67	59.02	112.56	3.26	102.27	11.84
T7	3.90	31.67	28.11	22.32	3.26	34.28	9.74
T8	10.57	66.67	45.90	43.42	5.96	37.96	10.26
T9	11.25	66.67	53.85	49.69	0.79	69.97	10.79

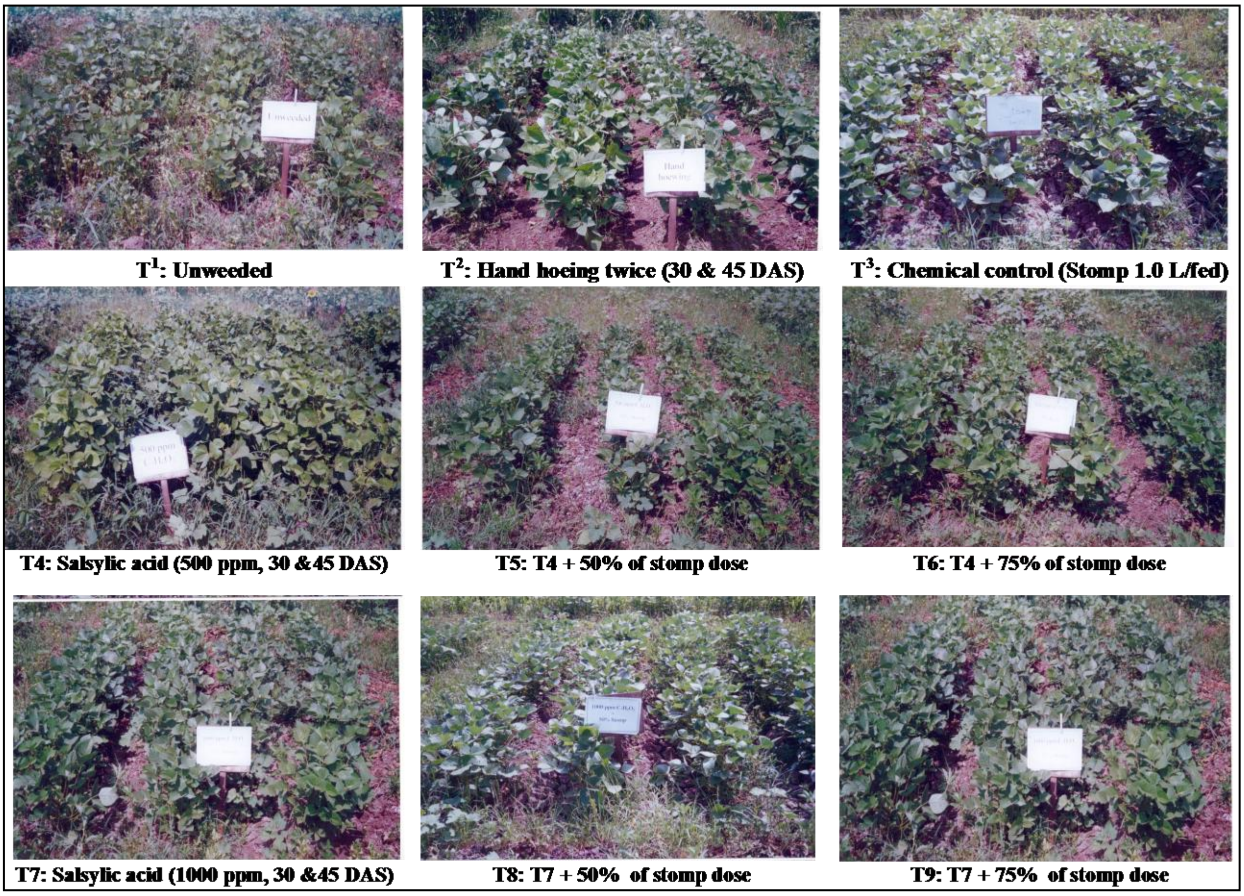
*Explanations including conditions of application are as in table (1).

Table (4): Influence of exogenous application of salicylic acid and/or reduced doses of stomp herbicide on mung bean yield (ton/fed).

Treatments*	Yield (ton fed^{-1})	Increasing % of control
T1	0.56	--
T2	1.26	125.00
T3	1.12	100.00
T4	0.89	58.93
T5	0.97	73.21
T6	1.06	89.29
T7	0.67	19.64
T8	0.72	28.57
T9	0.84	50.00
$LSD_{5\%}$	**0.04**	
CV%	**2.93**	

CV, Coefficient of variation,

*Explanations including conditions of application are as in table (1).



T1: Unweeded | **T2: Hand hoeing twice (30 & 45 DAS)** | **T3: Chemical control (Stomp 1.0 L/fed)**

T4: Salsylic acid (500 ppm, 30 &45 DAS) | **T5: T4 + 50% of stomp dose** | **T6: T4 + 75% of stomp dose**

T7: Salsylic acid (1000 ppm, 30 &45 DAS) | **T8: T7 + 50% of stomp dose** | **T9: T7 + 75% of stomp dose**

Figure (1): Influence of exogenous application of salicylic acid and/or reduced doses of stomp herbicide on mung bean and weed growth (65 DAS). Conditions of application are as in table (1).

DISCUSSION

Plant secondary metabolites have numerous applications in weed control domain. They can be used directly in the field on the pattern of herbicides [40], as structural indicators/skeletons for developing new synthetic herbicides [19; 21], or by mixing with commonly used synthetic herbicides [20; 23]. The latter has received considerable attention from a large segment of researchers around the world for health-related and ecological reasons [24-25; 41-42].

The main purpose of our research includes the application of low doses of stomp herbicide in combination with salicylic acid to reduce high dose of the pesticide input in mung bean production and the consequent environmental pollution. Mung bean growth, yield characteristics and accompanying weeds as influenced by salicylic acid/stomp applications were investigated in this regard.

The results from filed application showed high efficiency of all treatments including the sole and combined applications. Salicylic acid/stomp combinations, however, showed distinctive influences over both weed and crop growth. Multiple comparisons of treatments versus control showed no much significant differences between combined applications and the full dose of the herbicide in affecting either weed or crop growth/yield. A high crop growth and grain yield were generally obtained because of the good control of weeds. According to the current results, salicylic acid action is assumed to be driven by its capacity to synergistically/additively enhance the herbicidal efficacy of stomp. A great deal of attention from research community has been forward to using plant-derived compounds and plant water extracts to enhance herbicides activity via using them at rates less than recommended doses; great achievements were recorded in this respect [16; 41-;43-47].

Crop residues with potent allelopathic potential have been also highly successful in management weed growth and reducing application rates of synthetic herbicides [41;48-51]. Our results coincide partially with published research findings in this regard where an effective weed control and a mung bean yield comparable to using full dose of the herbicide were obtained.

The combined treatments containing 500 ppm salicylic acid were more effective than those containing 1000 ppm salicylic acid, either in controlling weeds, increasing crop growth, or improving crop productivity. Salicylic acid (500 ppm)/stomp (75% of the recommended dose) combination ranked first, suggesting that activity can be dose dependent. This treatment provided effective weed control and caused significant improvement in grain yield to a degree equal, to a greater extent, the full dose of the herbicide. Salicylic acid and its derivates (*e.g.*, salicylates) are well known by their herbicidal properties and do serve as strong allelochemicals against weeds growth in nature [52]. They are candidates as natural herbicides [53]. More significant results have been documented showing that exogenous salicylic acid (besides many other phenolic substances) substantially act in promoting the allelopathic potential of rice [54].

Hand weeding twice (at 30 and 45 DAS) gave significantly the best results both over controlling weeds and increasing grain yield. Salicylic acid at 500 ppm plus stomp at 75% of the recommended dose was the next best effective and profitable weed control measure. Stomp at the recommended label dose may be more effective, but is associated with a greater cost and more environmental pollution. Research on weed control treatments refers to a key fact that hand weeding is the best effective natural weed control method and a viable option for many of the intractable weeds, but can't be relied upon because of the high labour costs in many places [55-58].

CONCLUSION

In conclusion, even though stomp at the recommended dose and hand weeding twice treatments achieved the best results, the interacting effects of salicylic acid and stomp herbicide were also prominent and can be relied upon. Salicylic acid at 500 ppm induced greater effects in this regard. The economic return of using low doses of herbicides beside plant-derived chemical compounds is encouraging. In addition it is environmentally acceptable as effective and safe option. The use of herbicides at reduced doses is currently considered one of the most important techniques to limit herbicide input into the environment and agricultural production.

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