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Unraveling the effect of structurally different classes of insecticide on germination and early plant growth of soybean [*Glycine max* (L.) Merr.]

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ABSTRACT

Although a considerable number of studies about the effect of different insecticides on plant physiology and metabolism have been carried out, research work about the comparative action of structurally different classes of insecticide on physiological and biochemical properties of soybean seed germination and early growth has not been found. The objective of this study was to investigate the effect of different classes of insecticides on soybean seed germination and early plant growth. Soybean seeds of Bosuk cultivar were soaked for 24 h in distilled water or recommended dose (2 mL L^{-1}, 1 mL L^{-1}, 0.5 g L^{-1}, and 0.5 g L^{-1} water for insecticides Mepthion, Myungtaja, Actara, and Stonate, respectively) of pesticide solutions of four structurally different classes of insecticides – Mepthion (fenitrothion; organophosphate), Myungtaja (etofenprox; pyrethroid), Actara (thiamethoxam; neonicotinoid), and Stonate (lambda-cyhalothrin cum thiamethoxam; pyrethroid cum neonicotinoid) – which are used for controlling stink bugs in soybean crop. Insecticides containing thiamethoxam and lamda-cyhalothrin cum thiamethoxam showed positive effects on seedling biomass and content of polyphenol and flavonoid, however fenitrothion insecticide reduced the seed germination, seed and seedling vigor, and polyphenol and flavonoid contents in soybean. Results of this study reveal that different classes of insecticide have differential influence on physiologic and metabolic actions like germination, early growth, and antioxidant activities of soybean and this implies that yield and nutrient content also might be affected with the application of different types of insecticide.

1. Introduction

Soybean [*Glycine max* (L.) Merr.] is one of the most important crops worldwide that provides two third of calories derived from agriculture [1] and accounts for half of the global demand for oil and vegetable protein [2,3]. Production of soybean could be increased if the loss from pests is minimized [4]. Among the different insects that attack the crop, piercing-sucking bugs are noteworthy for feeding directly from the pods, seriously affecting crop yields [5]. Use of different agrochemicals has been significantly increased to control the insect pests in soybean [6].

Pesticides may cause changes in plant metabolism and affect nutritional patterns [7]. The organophosphate insecticides monocrotophos and phosphamidon increased concentrations of nitrogen and phosphorus in rice plants [8]. Cucumber growth was negatively affected by spraying insecticide malathion (organophosphate) and sevin (carbamate) with the lowest effect for the recommended dose [9]. Although no germination effects of insecticides karate (lambda-cyhalothrin), diazinon (organophosphate), and regent (fipronil) exposure were observed, significant growth effects were noted between pesticide treatments [10]. Triazophos (organophosphate) significantly decreased the rate but increased the time of germination of wheat with the increasing concentration of the insecticide [11]. Thiamethoxam (neonicotinoid) accelerated germination of soybean seeds under water deficit condition [12]. Two organophosphate systemic insecticides acephate and chlorpyrifos greatly inhibited *Pinus halepensis* seed germination while oxamyl, a carbamate systemic insecticide completely suppressed it showing varied toxicity to seeds and seedlings [13]. Seeds treatment with neonicotinoid containing insecticide significantly increased the number of germinating seeds and freezing tolerance of seedlings of spring wheat cultivars [14]. Application of thiamethoxam (neonicotinoid) affected the physiological and biochemical characteristics of rice crops [15] and also influenced the harvest index of spring wheat [16].

Although a considerable number of scientific literature about the effect of different insecticides on plant physiology and metabolism have been published, research works about the comparative action of structurally different classes of insecticide on physiological and biochemical properties of soybean seed germination and growth have not been found. The objective of this study was to investigate the physiological and biochemical mechanisms of soybean seed germination and early

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plant growth influenced by different classes of insecticide used for controlling stink bugs. This study may provide an insight into the potential influence of different classes of insecticides on plant growth, development, and possibly on nutrient value of crops as Crinnion [17] reviews that nutrient content of crops varies from farmer to farmer and year to year.

2. Materials and methods

2.1. Seed material and insecticide treatment

Seeds of soybean [*G. max* (L.) Merr.] cultivar Bosuk were treated by soaking for 24 h in distilled water or recommended dose (2 mL L^{-1}, 1 mL L^{-1}, 0.5 g L^{-1}, and 0.5 g L^{-1} water for insecticides Mepthion, Myungtaja, Actara, and Stonate, respectively) of four structurally different classes of insecticide which are used for controlling stink bugs in soybean, namely Mepthion (fenitrothion; organophosphate), Myungtaja (etofenprox; pyrethroid), Actara (thiamethoxam; neonicotinoid), and Stonate [lambda-cyhalothrin cum thiamethoxam (LT); pyrethroid cum neonicotinoid]. Detailed information of the insecticides has been mentioned in Table 1. Pesticide solutions were prepared in distilled water and untreated control seeds were soaked in distilled water.

2.2. Germination test

Seed germination test was carried out in incubator (25 ± 1 °C) in dark. After 24 h of seed soaking, insecticide treated and untreated control seeds were drained out and kept for germination until 4 days. The seeds were kept into petri dish (diameter: 9 cm) on a single layer of Whatman No. 1 filter paper and put 3 mL of distilled water. Thirty seeds were kept into each petri dish and 3 replications (30 seeds per replication) were maintained for each treatment. In order to maintain moisture 3 mL of distilled water was added to the petri dishes daily. Radicle protruding through the seed coat was considered as germinated [18]. The number of germinated seeds was counted every day until 4 days.

2.3. Seed vigor index and seedling vigor

The experiment was carried out at greenhouse of Kyungpook National University, Daegu, South Korea from July to August of 2015. The temperature of the experiment period ranged from 26 to 32 °C (60% average relative humidity and 14 h photoperiod). After 24 h of soaking in insecticide solutions or distilled water, insecticide treated and untreated control seeds were drained out and sown into plastic trays (10 × 5 hills) filled with sand. Fifty seeds were sown in 3 replications (50 seeds per replication) for each treatment. The seed vigor index (SVI) was calculated according to Copeland and McDonald [19] using the formula given below:

$$\mathrm{SVI} = \frac{\text{Number of seeds germinated on first count}}{\text{Days of the count}} + \ldots + \ldots + \frac{\text{Number of seeds germinated on last count}}{\text{Days of the last count}}$$

Seedling vigor was calculated using biomass method followed by Anto and Jayaram [20] with some modifications. Seedlings were carefully uprooted after 14 days of sowing and washed to remove the sand particles in running tap water. In order to remove the surface water, the seedlings with cotyledons were blotted and kept in hot air oven (60 °C) until constant weight was obtained. The seedling vigor was expressed as biomass per seedling. Fifteen seedlings from each treatment and replication were taken for measurement.

Table 1
Names (trade, common, and chemical), formulation, chemical class, and recommended dose of insecticides used in the present study.

Trade/brand name	Common name/active ingredient	Chemical name	Formulation	Chemical class	Recommended dose
Mepthion	Fenitrothion	O,O-Dimethyl O-4-nitro-m-tolyl phosphorothioate	Emulsifiable concentrate (EC)	Organophosphate	2 mL L^{-1} water
Myungtaja	Etofenprox	2-(4-Ethoxyphenyl)-2-methylpropyl-3-phenoxybenzyl ether	Emulsion, oil in water (EW)	Pyrethroid	1 mL L^{-1} water
Actara	Thiamethoxam	3-(2-Chloro-thiazol-5-ylmethyl)-5-methyl-[1,3,5]oxadiazinan-4-ylidene-N-niroamine	Granule (GR)	Neonicotinoid	0.5 g L^{-1} water
Stonate	Lambda-cyhalothrin + thiamethoxam	Cyano-(3-phenoxyphenyl)methyl-3-(2-chloro-3,3,3-trifluoro-1--propenyl)-2,2-dimethylcyclopropanecarboxylate + 3-(2-Chloro-thiazol-5-ylmethyl)-5-methyl-[1,3,5]oxadiazinan-4-ylidene-N-niroamine	Granule (GR)	Pyrethroid + neonicotinoid	0.5 g L^{-1} water