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Effect of Plant Growth Regulators and Their Time of Application on Yield Attributes and Quality of Soybean

Sonia Khatun[1], Tuhin Suvra Roy[1], Md. Nazmul Haque[1*] and Badshah Alamgir[2]

[1]Department of Agronomy, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh.
[2]Department of Biotechnology, Polytechnic Institute of New York University (NYU), New York, USA.

Authors' contributions

This work was carried out in collaboration between all authors. Author SK designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors TSR and MNH analyses of the study performed and final proof submission. Author BA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Plant growth regulators play important roles in plant growth and development, but little is known about the roles of plant growth regulators in yield components and seed qualities of soybean. In this study, salicylic acid, gibberellic acid (GA_3), kinetin and distilled water (control) were sprayed to soybean (BARI Soybean-6) at the vegetative stage, flower initiation stage, pod initiation stage, flower + pod initiation stage in the pot experiment under field condition during November, 2013 to March, 2014. Treatments were arranged in a Randomized Complete Block Design (RCBD) with five replications. The different plant growth regulators and their time of application showed significant effect on number of pods plant^{-1}, pod length, number of seeds pod^{-1}, 100-seed weight, stover yield, biological yield, harvest index, seed grading (% by weight), protein and moisture content in seed of soybean. Salicylic acid gave the highest number of seeds pod^{-1}, harvest index, small size seed, protein and moisture content in seed (1.60, 39.06%, 19.47%, 44.56% and 12.91%, respectively).

**Corresponding author: E-mail: sumon2539@gmail.com;*

Kinetin spray produced the maximum 100-seed weight (11.58 g). Application of growth regulators at vegetative stage produced the highest stover yield (6.46 g plant^{-1}), flower initiation stage gave the larger size seed (59.09%), pod initiation stage showed the maximum pod length (2.43 cm), highest moisture content in seed (13.50%) and spray at flower + pod initiation stage produced the maximum 100-seed weight (12.00 g), harvest index (43.42%), medium size seed (32.53%), protein content in seed (44.31%). Among the treatment combinations the application of salicylic acid at flower and pod initiation stage showed the highest yield attributes and maximum protein content compared to those of other growth regulators.

Keywords: Foliar spray; Glycine max; harvest index; protein content in seed; seed size.

1. INTRODUCTION

Soybean (*Glycine max* L.) belongs to the family Leguminosae, sub-family Faboideae is one of the leading oil and protein containing crops of the world. It is the most important grain legume of the world and a new prospective crop for Bangladesh [1]. Because of its high nutritional value and myriad form of uses, it is recognized as 'Golden Bean' and has become the miracle crop of the 21st century.

The climatic and the edaphic conditions of Bangladesh are favorable for soybean production. Soybean can be cultivated throughout the year in Bangladesh. In farmer's field average yield of soybean is much lower due to lack of improved agricultural practices of which different plant growth regulators is an important determinant for better performance of soybean. The potential yield of the soybean crop is mainly influenced by the production, fixing and transformation of the reproductive structures into pods with the seeds, thus the spatial dynamics of these structures need to be studied and correlated with yield [2]. Reports so far been made to indicate a promising results on yield of soybean and other oil crops due to the use of bio-chemical substances or plant growth regulator such as salicylic acid, gibberelic acid (GA_3), kinetin etc.

Salicylic acid ($C_7H_6O_3$) is an endogenous growth regulator of phenolic nature, which participates in the regulation of physiological processes in plant, such as ion uptake and transport, inhibition of ethylene biosynthesis, transpiration [3,4], stomatal regulation under abiotic stress conditions [3,5]. It plays a vital role in plant growth, plant water relations [6]. Foliar application of salicylic acid exerted a significant effect on plant growth metabolism when applied at physiological concentration and thus acted as one of the plant growth regulating substances [7]. Salicylic acid (50 ppm) increased the yield contributing characters and quality of soybean compared to control [8]. GA_3 plays an essential role in many aspects of plant growth and development, stem elongation and flower development [9]. The lower concentration (100 ppm) of GA_3 resulted in increased number of pods plant^{-1}, seeds plant^{-1}, 100-seed weight and seed yield plant^{-1} of soybean more efficiently than the higher concentration (200 ppm) and the control [10]. Kinetin is known to stimulate or inhibit a great number of physiological processes. For soybean, however, great variability can be observed in reported results. Kinetin can be utilized in a variety of applications, from the treatment of seeds [11] to applications during flowering [12] and the same is true about GA_3 [13-15]. The highest kinetin concentrations resulted in the highest yields of soybean. Kinetin application (1000 mg ha^{-1}) resulted in an increase of 27.1 and 27.4% yield plant^{-1} and total set pods plant^{-1} in contrast to the control [16]. The growth regulator salicylic acid enhances the plant growth, flower induction, nutrient uptake and photosynthesis [17]. Therefore, flower and pod dropping of soybean can be minimized by using GA_3, kinetin, and salicylic acid.

However, the studies investigating the role of plant growth regulators application at different growth stages in soybean are largely lacking. Under the above perspective and situation, a study has been carried out to determine optimum concentration and time of application of plant growth regulators for maximizing yield related attributes and quality of soybean.

2. MATERIALS AND METHODS

2.1 Site Description

The experiment was conducted at the Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 7, 2013 to March 23, 2014 in Rabi season which was situated at 23°46′ N latitude and 90°23′ E

longitude at an altitude of 8.45 meter above the sea level. The soil of the experimental site was sandy loam with pH and cation exchange capacity 5.6 and 2.64 meq/100 g soil, respectively. The experimental site is under subtropical humid climatic conditions and the weather condition during the experiment is presented in Fig. 1.

2.2 Experimental Treatments, Planting Material, Design and Pot Size

The experiment consisted of four different plant growth regulators *viz.,* H_0= Control (water), H_1= Salicylic acid (50 ppm), H_2= GA_3 (100 ppm), H_3= Kinetin (500 ppm) and four different time of application *i.e.,* S_1= Vegetative stage [25 days after sowing (DAS)], S_2= Flower initiation stage (40 DAS), S_3= Pod initiation stage (50 DAS), S_4= Flower + pod initiation stage (40 DAS and 50 DAS). The variety BARI soybean-6 was used as the test crops. The two factors experiment was arranged in Randomized Complete Block Design (RCBD) with five replications. Each replication comprised of 16 pots where 16 treatment combinations were allotted at random. There were 80 unit pots altogether in the experiment. The size of each pot was 9.5 inch in diameter and 10.5 inch in height. Three seeds were sown and plants thinned to one per pot when the first trifoliate leaf emerged.

2.3 Preparation of the Pots

The experimental pots were first filled with 10 kg soil. Potted soil was brought into desirable fine tilth by hand mixing. The stubble and weeds were removed from the soil and then cowdung was mixed. The soil was treated with insecticides (4 kg cinocarb 3G ha^{-1}) at the time of final pot preparation to protect young plants from the attack of soil inhibiting insects such as cutworm and mole cricket.

2.4 Fertilizer Application and Sowing of Seeds in the Pot

Urea, Triple super phosphate (TSP), Muriate of potash (MoP), gypsum, boric acid and molybdenum were used as a source of nitrogen, phosphorous, potassium, sulphur, boron and molybdenum, respectively. The fertilizers urea, TSP, MoP, gypsum, boric acid and molybdenum were applied at the rate of 42, 105, 72, 57.5, 0.025 and 0.013 g pot^{-1}, respectively following the Bangladesh Agricultural Research Institute (BARI) recommendation [18]. All of the fertilizers were applied during the final pot preparation. BARI Soybean-6 seeds were sown in the pots at a depth of 2-3 cm. During seed sowing 0.5 g Bavistin were mixed with seeds.

2.5 Preparation and Application of Plant Growth Regulators

Gibberellins and Kinetin solution dissolved in 20 mg NaOH and then mixed with 500 ml water. Salicylic acid was dissolved in ethanol for preparation of solution. Plant growth regulators were foliar sprayed as per treatment. Salicylic acid (50 ppm), GA_3 (100 ppm), Kinetin (kinetin puriss CHR: 6-Furfurylaminopurine, $C_{10}H_5OH$) (500 ppm) and water were each applied, using a mini hand sprayer, separately, to the canopy (including leaves and racemes) of plants each until incipient runoff (approx. 10 mL aqueous solution per plant). The control plants were sprayed with the same amount of water.

2.6 Biological Yield

Biological yield was calculated by using the following formula:

Biological yield= Seed yield + Stover yield

2.7 Harvest Index (%)

Harvest index is the relationship between seed yield and biological yield [19]. It was calculated by using the following formula:

$$\text{HI (\%)} = \frac{\text{Seed yield}}{\text{Biological yield}} \times 100$$

2.8 Seed Grading (% by Weight)

Seeds harvested from each pot were graded by weight into the large, medium, small and converted to percentage. Greater than 135 g, 100-135 g and less than 100 g per 1000-seed weight regarded as large, medium and small size seed respectively.

2.9 Moisture and Protein Percentage

After collecting the seed, the seed samples were sun dried and then packed in polythene bag by proper labeling. These labeled packed samples were immediately sent to Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka for determination of moisture percentage and crude protein percentage.

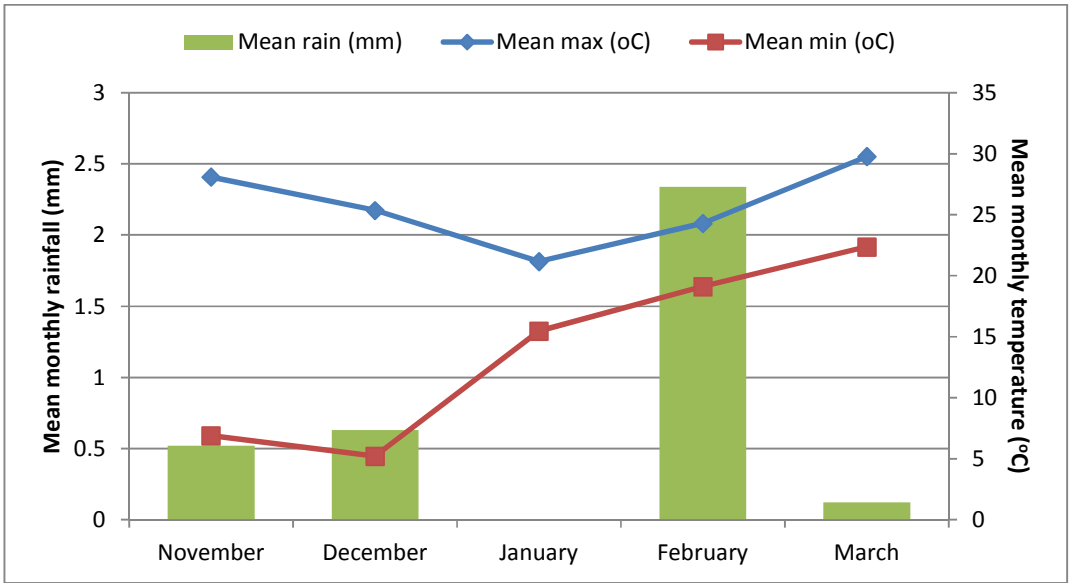

Fig. 1. Mean maximum, minimum temperature and rainfall during the experimental period

2.10 Statistical Analysis

Collected data on different parameters were statistically analyzed by using MSTAT-C [20] program and mean differences among the treatments were compared by Least Significant Difference (LSD) test at 5% level of probability.

3. RESULTS AND DISCUSSION

3.1 Number of Pods Plant^{-1}

Number of pods plant^{-1} had no significant effect on plant growth regulators at different time of application (Table 1). Interaction of different plant growth regulators and their time of application on the number of pods plant^{-1} of soybean showed significant variation (Table 2). When GA_3 applied at flower + pod initiation stage produced the highest number of pods plant^{-1} (41.00) which was statistically similar with kinetin spray at vegetative stage and the lowest (19.60) was obtained from water spray at vegetative stage. Copur et al. [21] assessed significantly maximum number of pods plant^{-1} was recorded in all the concentrations of NAA followed by GA_3 and Kinetin on cotton. The foliar application of plant growth regulators at flower initiation and pod formation stage might have reduced flower drop and caused efficient translocation of photosynthates from source to sink. This might have significantly increased the number pods plant^{-1} as reported by Ganapathy et al. [22] on rice. Similar results were observed by Khalil and Mandurahm [23].

3.2 Pod Length

Application of different plant growth regulators showed non-significant effect and their time of application had significant effect on pod length of soybean (Table 1). The highest pod length (2.43 cm) was obtained from pod initiation stage which was statistically at par with flower and flower + pod initiation stage whereas, lowest (2.18 cm) was obtained from vegetative stage. Interaction of plant growth regulators and their time of application had significant effect on pod length of soybean (Table 2). The longest pod length (2.60 cm) was recorded from salicylic acid when applied at flower initiation stage which was statistically similar with GA_3 spray at flower + pod initiation stage and the shortest (2.00 cm) was recorded from water spray at vegetative stage. Cross et al. [24]; Dhankhar and Singh [25] reported the increased pod length due to GA_3 application.

3.3 Number of Seeds Pod^{-1}

Number of seeds pod^{-1} was increased significantly with plant growth regulators application (Table 1). The highest number of seeds pod^{-1} (1.60) was counted from salicylic acid which was statistically at par with GA_3 100 ppm and the lowest (1.30) was obtained from water.

Table 1. Effect of different hormone and their time of application on yield parameters of soybean

Treatment	Number of pods plant^{-1}	Pod length (cm)	Number of seeds pod^{-1}	100-seed weight (g)	Stover yield (g plant^{-1})	Biological yield (g plant^{-1})	Harvest index (%)
Different hormones							
H_0	23.55	2.25	1.30 b	9.66 b	6.34	8.96	26.51 b
H_1	27.60	2.39	1.60 a	10.87 ab	5.63	9.74	39.06 a
H_2	30.40	2.38	1.44 ab	10.05 ab	5.32	8.85	37.19 a
H_3	27.65	2.39	1.54 a	11.58 a	6.39	10.48	37.27 a
$LSD_{(0.05)}$	ns	ns	0.197	1.841	ns	ns	8.353
Time of application							
S_1	29.45	2.18 b	1.42	9.65 b	6.46 a	10.02	33.81 b
S_2	27.10	2.40 ab	1.42	9.58 b	5.82 ab	8.97	33.18 b
S_3	25.00	2.43 a	1.49	10.93 ab	6.24 ab	9.35	29.61 c
S_4	27.65	2.39 ab	1.54	12.00 a	5.15 b	9.70	43.42 a
$LSD_{(0.05)}$	ns	0.219	ns	1.841	1.206	ns	8.353

In a column, values with different letter(s) differed significantly at 5% level as per LSD.
H_0 = Control (water), H_1 = Salicylic acid (50 ppm), H_2 = GA_3 (100 ppm), H_3 = Kinetin (500 ppm). S_1= Vegetative stage at 25 DAS, S_2 = Flower initiation at 40 DAS, S_3 = Pod initiation at 50 DAS and S_4 = Flower +Pod initiation stage at 40 and 50 DAS

Table 1 showed that salicylic acid increased 23% number of seeds pod^{-1} over control. Number of seeds pod^{-1} had non-significant effect on different time of application (Table 1). Interaction effect of plant growth regulators and their time of application had significant effect on number of seeds pod^{-1} of soybean (Table 2). The maximum number of seeds pod^{-1} (1.76 cm) was recorded from salicylic acid and kinetin spray at vegetative, pod initiation and flower + pod initiation stage which is statistically similar with GA_3 spray at flower + pod initiation stage whereas, the minimum (1.12 cm) was found from water spray at vegetative stage. Devi et al. [8] observed that number of seeds of soybean increased by the application of 50 ppm salicylic acid at flower + pod initiation stage. These findings also correlate the above mentioned findings.

3.4 100-seed Weight

100-seed weight of soybean showed significant variation in terms of plant growth regulators application (Table 1). Table 1 showed that kinetin increased 20% 100-seed weight over control. Zholobak [26] reported that kinetin treatment increased the weight of seeds. 100-seed weight had significant effect on different time of application (Table 1). The maximum 100-seed weight (12.00 g) was obtained from flower + pod initiation stage and the minimum (9.65 g) was recorded from vegetative stage. It might be due to increased mobilization of metabolites to the reproductive sinks increased the 100-seed weight. Devi et al. [8] observed that 100-seed weight of soybean increased by the application of 500 ppm kinetin at flower+ pod initiation stage. Interaction of plant growth regulators and their time of application had significant effect on 100-seed weight of soybean (Table 2). The highest 100-seed weight (16.79 g) was observed from salicylic acid with flower + pod initiation stage which was statistically at par with kinetin spray at pod initiation stage and the lowest (7.99 g) was calculated from salicylic acid when sprayed at flower initiation stage.

3.5 Stover Yield

Stover yield of soybean had no significant effect on plant growth regulators application (Table 1). Different time of application also influenced significantly the stover yield of soybean (Table 1). The highest stover yield (6.46 g plant^{-1}) was produced from vegetative stage which was statistically similar with flower and pod initiation stage while the minimum (5.15 g plant^{-1}) was found from flower + pod initiation stage. Interaction of plant growth regulators and their time of application had significant effect on yield of soybean (Table 2). The maximum stover yield (6.92 g plant^{-1}) was recorded from water when sprayed at vegetative stage and the lowest (4.48 g plant^{-1}) was obtained from GA_3 spray at flower + pod initiation stage. It might be due to more efficient diversion of energy from source to sink.

3.6 Biological Yield

Biological yield of soybean exerted non-significant effect on plant growth regulators spray and their time of application (Table 1). Interaction effect of plant growth regulators and time of application had significant effect on biological yield of soybean (Table 2). The highest biological yield (11.20 g plant^{-1}) was recorded from kinetin when applied at vegetative stage which was statistically at par with all treatment combinations except GA_3 with flower initiation stage. Copur et al. [21] assessed variation in biological yield for all the concentrations of NAA followed by GA_3 and Kinetin. The stover and biological yield increased due to cumulative effect of yield attributing characters and enhanced photosynthetic efficiency and greater diversion of assimilates towards reproductive organs.

3.7 Harvest Index

Harvest index of soybean had significant effect on plant growth regulators application (Table 1). The highest harvest index (39.06%) was recorded from salicylic acid and the lowest (26.51%) was found from control water. Salicylic acid increased harvest index 40% over control. Different time of application also influenced significantly the harvest index of soybean (Table 1). The highest harvest index (43.42%) was obtained from flower + pod initiation stage and the lowest (29.61%) was recorded in pod initiation stage. Interaction of plant growth regulators and their time of application had significant effect on harvest index of soybean (Table 2). The highest harvest index of soybean (52.76%) was recorded from salicylic acid spray at flower + pod initiation stage which was statistically similar with GA_3 spray at vegetative and flower + pod initiation stage, kinetin with vegetative and flower initiation stage whereas, the minimum (21.85%) was found from water spray at vegetative stage.

3.8 Seed Grading (% by Weight)

Plant growth regulators application had no significant effect on percent of large and medium size seed but had significant effect on percent of small size seed (Table 3). Table 3 showed that 52-58% seeds were regarded as large size and 27-30%, 14-20% were medium and small size seed, respectively. Significant amount of large and medium size seed were produced by time of application but in case of small size seed there was no significant effect (Table 3).

Table 2. Interaction effect of different hormone and their time of application on yield parameters of soybean

Treatment combination	Number of pods plant^{-1}	Pod length (cm)	Number of seeds pod^{-1}	100-seed weight (g)	Stover yield (g plant^{-1})	Biological yield (g plant^{-1})	Harvest index (%)
H_0S_1	19.60 c	2.00 d	1.12 e	8.33 cd	6.92 a	8.79 ab	21.85 c
H_0S_2	20.40 bc	2.16 b-d	1.24 c-e	9.73 cd	6.30 ab	8.17 ab	22.11 c
H_0S_3	28.60 a-c	2.50 a-c	1.48 a-e	9.26 cd	6.64 ab	10.44 ab	28.41 bc
H_0S_4	25.60 a-c	2.32 a-d	1.36 b-e	11.29 b-d	5.50 ab	8.43 ab	33.67 bc
H_1S_1	32.80 a-c	2.10 cd	1.28 c-e	9.27 cd	6.83 ab	10.14 ab	30.77 bc
H_1S_2	25.60 a-c	2.60 a	1.60 a-c	7.99 d	5.96 ab	9.49 ab	37.07 a-c
H_1S_3	28.00 a-c	2.52 a-c	1.76 a	9.43 cd	5.00 ab	8.22 ab	35.78 bc
H_1S_4	24.00 a-c	2.32 a-d	1.76 a	16.79 a	4.71 ab	11.10 a	52.76 a
H_2S_1	27.80 a-c	2.22 a-d	1.54 a-d	11.02 b-d	5.42 ab	9.94 ab	42.62 ab
H_2S_2	29.80 a-c	2.36 b-d	1.32 b-e	8.81 cd	4.57 ab	7.06 b	31.46 bc
H_2S_3	23.00 bc	2.36 a-d	1.20 de	11.31 b-d	6.80 ab	8.98 ab	21.91 c
H_2S_4	41.00 a	2.56 ab	1.68 ab	9.05 cd	4.48 b	9.43 ab	52.51 a
H_3S_1	37.60 ab	2.42 a-d	1.76 a	9.98 cd	6.69 ab	11.20 a	39.99 ab
H_3S_2	32.60 a-c	2.48 a-c	1.52 a-d	11.77 bc	6.450 ab	11.16 a	42.10 ab
H_3S_3	20.40 bc	2.32 a-d	1.52 a-d	13.73 ab	6.53 ab	9.75 ab	32.34 bc
H_3S_4	20.00 c	2.340 a-d	1.36 b-e	10.85 b-d	5.89 ab	9.83 ab	34.66 bc
$LSD_{(0.05)}$	17.440	0.438	0.394	3.682	2.412	4.015	16.710

In a column, values with different letter(s) differed significantly at 5% level as per LSD.
H_0 = Control (water), H_1 = Salicylic acid (50 ppm), H_2 = GA_3 (100 ppm), H_3 = Kinetin (500 ppm). S_1= Vegetative stage at 25 DAS, S_2 = Flower initiation at 40 DAS, S_3 = Pod initiation at 50 DAS and S_4 = Flower +Pod initiation stage at 40 and 50 DAS

Among the time of application 59.09% larger seed produced by flower initiation stage. Vegetative and pod initiation also showed the statistically at par result. Among the plant growth regulators application 32.53% medium seed produced by flower + pod initiation stage. Plant growth regulators and their time of application exerted significant effect on different seeds size (large, medium and small size) (Table 4). In case of large size seed, the highest grade of seed (65.43%) was produced by the combination of GA_3 and flower initiation stage which was statistically similar with water spray at flower initiation stage whereas, the lowest (43.46%) was found from the combination of GA_3 with flower + pod initiation stage. In case of medium, the highest grade of seed (34.42%) was produced by the combination of control and flower + pod initiation stage, which was statistically at par with water spray at vegetative, flower and pod initiation stage, salicylic acid with vegetative, pod, flower and flower + pod initiation stage, GA_3 with vegetative, pod, flower + pod initiation stage, kinetin with vegetative, flower, pod and flower + pod initiation stage whereas, the lowest (21.84%) was produced by GA_3 spray at flower initiation stage. In case of small size seed, highest grade of seed (24.26%) was produced by the combination of GA_3 and flower + pod initiation stage, which was statistically similar with salicylic acid spray at vegetative, flower and pod initiation stage, kinetin with vegetative and flower + pod initiation stage whereas, lowest (7.76%) was produced from combination of water spray and flower + pod initiation stage.

3.9 Protein Percentage

Application of plant growth regulators showed significant effect on protein percentage of soybean seed (Table 3). The highest protein percentage (44.56%) was recorded from salicylic acid and the lowest (42.29%) was obtained from water spray. Khodary [27] indicated that salicylic acid can enhance the protein percentage of soybean. Different time of application also significantly influenced the protein percentage of soybean seed (Table 3). The maximum protein percentage (44.31%) was found from flower + pod initiation stage while the minimum (43.35%) was attained from vegetative stage. Interaction of plant growth regulators and their time of application had significant effect on protein percentage of soybean seed (Table 4). The highest protein percentage (45.02%) was recorded from salicylic acid spray at flower initiation stage which was statistically at par with salicylic acid spray at vegetative and pod initiation stage, GA_3 with flower + pod initiation stage whereas, the lowest (41.53%) was obtained from water spray at vegetative stage.

Table 3. Effect of different hormone and their time of application on grading (% by weight), protein and moisture content of soybean seed

Treatments	Seed grading (% by weight)			Protein content in seed (%)	Moisture content in seed (%)
	Large	Medium	Small		
Different hormones					
H_0	57.60	28.75	13.65 b	42.29 c	13.73 b
H_1	51.50	29.03	19.47 a	44.56 a	12.91 a
H_2	56.13	27.10	16.77 ab	43.88 b	11.70 c
H_3	53.11	29.77	17.12 ab	43.89 b	12.88 b
$LSD_{(0.05)}$	ns	ns	5.320	0.630	0.304
Time of application					
S_1	53.04 ab	27.24 ab	19.73	43.35 b	12.38 c
S_2	59.09 a	25.59 b	15.32	43.54 b	12.71 b
S_3	55.15 ab	29.29 ab	15.56	43.42 b	13.50 a
S_4	51.06 b	32.53 a	16.41	44.31 a	12.63 bc
$LSD_{(0.05)}$	7.780	5.760	ns	0.630	0.304

In a column, values with different letter(s) differed significantly at 5% level as per LSD.
H_0 = Control (water), H_1 = Salicylic acid (50 ppm), H_2 = GA_3 (100 ppm), H_3 = Kinetin (500 ppm). S_1= Vegetative stage at 25 DAS, S_2 = Flower initiation at 40 DAS, S_3 = Pod initiation at 50 DAS and S_4 = Flower +Pod initiation stage at 40 and 50 DAS

Table 4. Interaction effect of different hormone and their time of application on grading (% by weight), protein and moisture content of soybean seed

Treatment combination	Seed grading (% by weight)			Protein content in seed (%)	Moisture content in seed (%)
	Large	Medium	Small		
H_0S_1	54.41 a-d	27.99 ab	17.60 a-c	41.53 f	13.33 b-d
H_0S_2	62.35 ab	24.13 ab	13.52 bc	42.20 ef	13.54 bc
H_0S_3	55.81 a-d	28.46 ab	15.73 a-c	41.87 ef	13.55 b
H_0S_4	57.82 a-d	34.42 a	7.766 c	43.58 b-d	13.35 b-d
H_1S_1	52.80 a-d	25.40 ab	21.80 ab	44.41 ab	12.65 ef
H_1S_2	49.01 b-d	29.71 ab	21.28 ab	45.02 a	12.50 e-g
H_1S_3	50.12 a-d	29.40 ab	20.49 ab	44.44 ab	14.68 a
H_1S_4	54.08 a-d	31.62 ab	14.30 a-c	44.35 a-c	12.94 c-e
H_2S_1	58.90 a-d	23.11 ab	17.99 a-c	43.52 b-d	10.61 h
H_2S_2	65.43 a	21.84 b	12.73 bc	43.93 a-d	10.90 h
H_2S_3	56.72 a-d	31.16 ab	12.11 bc	43.11 c-e	13.34 b-d
H_2S_4	43.46 d	32.28 ab	24.26 a	44.95 a	11.95 g
H_3S_1	46.03 cd	32.45 ab	21.52 ab	43.94 a-d	12.93 c-e
H_3S_2	59.56 a-c	26.70 ab	13.74 a-c	43.00 de	12.78 d-f
H_3S_3	57.94 a-d	28.13 ab	13.92 a-c	44.25 a-d	13.55 b
H_3S_4	48.89 b-d	31.81 ab	19.30 ab	44.35 a-c	12.27 fg
$LSD_{(0.05)}$	15.570	11.530	10.650	1.270	0.608

In a column, values with different letter(s) differed significantly at 5% level as per LSD. H_0 = Control (water), H_1 = Salicylic acid (50 ppm), H_2 = GA_3 (100 ppm), H_3 = Kinetin (500 ppm). S_1= Vegetative stage at 25 DAS, S_2 = Flower initiation at 40 DAS, S_3 = Pod initiation at 50 DAS and S_4 = Flower +Pod initiation stage at 40 and 50 DAS

3.10 Moisture Percentage

Moisture percentage of soybean seed varied significantly due to different treatments of plant growth regulator (Table 3). The highest moisture percentage (13.73%) was recorded from water spray and the lowest (11.70%) was determined from GA_3 application. Time of application had significant effect on moisture percentage of soybean seed (Table 3). The maximum moisture percentage (13.50%) was obtained from pod initiation stage and the minimum (12.38%) was observed from vegetative stage. Interaction of plant growth regulators and their time of application had significant effect on moisture percentage of soybean seed (Table 4). The highest moisture content (14.68%) was found from salicylic acid when applied at pod initiation stage and the minimum (10.61%) was calculated from GA_3 when sprayed at vegetative stage.

4. CONCLUSION

Based on the results of the present experiment, it may be concluded that kinetin performed the best in case of 100-seed weight. Among the time of application flower + pod initiation stage at, irrespective of plant growth regulators. Among the treatment combinations, application of salicylic acid (50 ppm) at flower + pod initiation stage would be promising practice for soybean yield and quality.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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