The effect of pre-soaking common bean (*Phaseolus vulgaris*) seeds in gibberellic acid solution on germination and seedling growth

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Abstract

Poor seed germination and early seedling growth often limit common bean production. Pre-treatment with plant hormones, such as gibberellic acid (GA_3), can improve germination and seedling vigour in many plants. However, its effects on common bean seeds are not well understood. This study evaluated GA_3's potential to promote germination and seedling growth in common beans. Laboratory germination tests and greenhouse trials were conducted using two varieties, Gloria and Nua45. Seed from each variety was divided into two groups and the other group was soaked in 60 ml/L GA_3 solution for 5 min and the other group was left untreated and used as a control. Treatments were arranged in a completely randomized design with three technical and two biological replicates. Data on germination percentage were collected every 24 hours for 120 h, along with measurements of rootlet length, seedling vigour indices, root length, shoot length, and dry weight. Results indicated that GA_3-treated Nua45 seeds had significantly higher germination percentages than untreated seeds after 48, 72, and 96 h, while treated Gloria seeds showed lower germination than untreated seeds within the same time frames. By 120 h, both treated and untreated seeds of both varieties reached a minimum of 90% germination. Nua45 seeds treated with GA_3 showed significantly greater rootlet length (5.29 cm) than untreated seeds (4.12 cm), while Gloria seeds showed no significant difference in rootlet length between treated (2.49 cm) and untreated seeds (2.86 cm). For Nua45, GA_3-treated seedlings had higher shoot length (46.7 cm), dry weight (4.10 g), and seedling vigour index II (3.7) than untreated seedlings (28.5 cm, 2.34 g, and 2.25, respectively). In contrast, untreated Gloria seedlings had greater root length (35.1 cm) than treated seedlings (14.4 cm), with no shoot length difference. These findings suggest that pre-soaking Nua45 seeds in GA_3 solution enhances germination and growth, while pre-soaking Gloria seeds reduces them. These findings suggest a hormone-genotype interaction effect warranting further study.

Keyword: *Phaseolus vulgaris*, Pre-soaking, Gibberellic acid, Seed germination, Seedling vigour, Nua45.

Introduction

Common bean (*Phaseolus vulgaris*) is the most widely cultivated crop for human nutrition among legumes worldwide (Smith and Rao, 2021). The global production of the crop is 28 million metric tons and covers an area of 35 million hectares (FAOSTAT, 2023). Common bean is highly nutritious providing a rich source of proteins, fibre, vitamins and other dietary necessities (Nasar *et al*., 2023). This makes it important as a component of a plant-based diet and for elimination of hunger and malnutrition. Common bean is an excellent protein substitute for meat. It can be consumed as cooked fresh pods or boiled dry grains. Its leaves are also eaten as green vegetables (Mangole *et al*., 2022; Uebersax *et al*., 2022). Moreover, its consumption is believed to reduce colon and breast cancer, and heart diseases (Mangole *et al*., 2022; Vidak *et al*., 2023). However, the yield of common beans in sub Saharan Africa (0.7 t/ha) is low compared to the developed world (1.2 t/ha) (Nedumaran *et al*., 2015). Poor crop stand which result from poor seed germination and reduced crop vigour during early seedling growth stages were identified as some of the causes of poor yield in common bean production (Dhal *et al*., 2022).

Seed germination and subsequent early seedling growth are the first crucial stages of a plant's life cycle (Kaur *et al*., 2023). Superior seed germination and seedling growth promotes good yield of crop plants (Sharma and Jain, 2016). Strong seedlings compete for growth factors such as sunlight better compared to poor seedlings. Moreover, vigorous seedlings tolerate stresses such as pest attack during growth.

Seed germination is dependent upon different factors which include external and internal factors (Erol and Arslanoğlu, 2022). The most important internal factors are the genetic composition, seed vigour and plant hormones. Plant hormones plays a central role where gibberellins promotes and abscisic acid inhibit germination in seeds of many plant species (Taiz and Zeiger, 2010), Some plant genes are activated in the presence of specific plant hormones (Miransari and Smith, 2014) and some plant hormones regulate seed vigour and synthesis of germination enzymes such as amylases and proteases (Troyjack *et al*., 2017).

Exogenous application of plant hormones is considered a promising approach to the functioning of the enzymatic and hormonal systems which promotes seed germination. Among plant hormones, gibberellic acid (GA_{3}, one of the active forms of gibberellins) has been found to be associated with seed germination, breaking of seed dormancy and synthesis of germination promoting enzymes such as hydrolases (Kaur *et al*., 2023; Erol and Arslanoğlu, 2022). It has been shown to break seed dormancy, enhance germination rates, and stimulate early seedling development in cucumber (Al Sahil, 2016), sweet corn (Zhu *et al*., 2019), soybean (Marinho et al., 2021), mung bean (Kaur et al., 2023) and sweet sorghum (Mohammed, 2023). Thus, GA_3 was hypothesized as a possible tool for increasing germination and early seedling growth of common beans. However, there is limited information on its specific effects on the germination and seedling growth of common beans. In a study with Mouro and BRS Embaixador bean varieties in Brazil, the first germination count of Mouro was increased by soaking seeds in GA_3 doses up to 91.5 mg L^{-1} and the first germination count of BRS Embaixador was decreased by soaking in a similar GA_3 dose (*Troyjack et al.,* 2017). Nevertheless, seedling plant height for both varieties was increased by GA_3 doses up to 200 mg L^{-1}. In another study, soaking bean seeds in GA_3 doses 0, 50, 100 and 200 mg L^{-1} was found to have no effect on germination, emergence, and some seedling growth attributes such as number of leaves, leaf area and dry mass of leaves (Jaques *et al.*, 2019). These contrasting results shows that the effect of soaking bean seeds in GA_3 solution has not been clearly established. The purpose of this study, was therefore, to access the potential of GA_3 as a germination and early seedling growth promoting agent in common beans. The main objective of the study was to explore the effects of pre-soaking common bean seeds in GA_3 solution on germination and early seedling growth. This was studied by comparing the germination and early seedling growth performance of two common bean varieties seeds pre-soaked in GA_3 solution.

Materials and Methods

Preparation of planting material

Two experiments, i.e., a laboratory germination test and a greenhouse trial, were carried out to compare the effect of pre-soaking common bean seeds in GA_3 solution on seed germination and early seedling growth. Two SeedCo common bean varieties, Gloria and Nua45, were used in both experiments. The seeds were supplied by Farm and City Centre (Farm and City Centre, Bulawayo). Seeds were randomly selected and sterilized by soaking in 1% sodium hypochlorite solution for 10 minutes and then washing 2 times with distilled water. Sterilized seed samples from each variety were divided into two groups. The other group was pre-soaked in 60 ml L^{-1} gibberellic acid (GA_3) solution for 5 minutes; according to the modified method of *Troyjack et al*. (2017). After pre-soaking, the seeds were blotted dry using a clean paper towel and sown immediately. The other group of sample seed per each variety was used as the untreated control.

The germination test

The germination test experiment was carried out in the Faculty of Natural Resources Management and Agriculture at Gwanda State University (Gwanda State University, Filabusi). Four treatments, i.e., treated Nua45 seeds (referred as Nua GA), untreated Nua 45 seeds (referred as Nua), treated Gloria seeds (referred as Gloria GA) and untreated Gloria seeds (referred as Gloria) were compared. Three replicates of ten seeds per replicate per treatment were arranged in a completely randomized design (CRD). Each group of ten seeds (replicate) were sown in a 90 mm × 15 mm Petri dish lined with two sheets of Whatman No. 1 filter papers wetted with 5 mL distilled water. The seeds were germinated in a growth chamber set at 21 ± 1 ℃ and alternating12 h darkness and light. Germinated seeds were counted at 24 h interval (daily) for a period of 120 h. The germinated seeds were discarded at each counting interval. Seeds were considered germinated when 2 mm of the radicle had visibly protruded through the seed coat. The germinated seeds per replicate per time interval were converted to percentages. This data was used to compute germination percentage. A similar experiment under the same germination conditions was carried out to measure the rootlet length. Five seeds per replicate per treatment were used and the rootlet length was measured after 120 h. Moreover, additional distilled water (2 ml in each Petri-dish) was added after 72 h from soaking to replenish moisture lost by evaporation. To measure rootlet length, three seedlings per replicate were randomly selected and the length (cm) of the longest rootlet was measured using a ruler. These experiments (to measure germination percentage and rootlet length) were repeated and data was averaged (for the data from different biological replicates were not significantly different $p > 0.05$). Seedling vigour index 1 was calculated using the formulae,

$$Seedling\ vigour\ Index\ 1\ (SVI\ I) = germination\ percentage\ x\ seedling\ length$$

Greenhouse Experiment

Seedling emergence and seedling growth of common bean seeds were studied under natural greenhouse conditions during the period 15 February to 08 March 2024. The seeds were prepared and treated the same way the germination test seeds were prepared and treated. Ten seeds (equal to a replicate) were sown in perforated polythene plastic bags (30 cm × 15 cm) filled with garden soil. Each treatment was replicated three times and the treatments were arranged in a completely randomized design (CRD). Emerged seeds were counted from 5 days after sowing to 8 days after sowing. The data was converted to percent and used to calculate emergence percentage. After counting, seedlings were allowed to grow for 14 days under natural greenhouse conditions. The seedlings were watered and weeded whenever necessary, however, no fertilizer was added. Shoot length, root length, seedling fresh weight and seedling dry weight were determined. Shoot length and root length were measured using a ruler. Fresh weight was determined by weighing three randomly selected seedlings per replicate on an electronic balance. The seedlings were carefully removed from the polyethylene bags (with intact root balls) and the soil forming the root balls was carefully washed away with tap water. Excess water on the roots was bolted using paper towel before weighting. For dry weight, three randomly selected seedlings per replicate were dried in an oven set at 70 °C for 72 h in a khaki envelop (Erol and Arslanoğlu, 2022) and then weighed on an electronic balance. Seedling vigour index II was calculated using the following formula;

$$Seedling\ vigour\ index\ 11\ (SVI\ II) = \%\ emergence\ x\ seedling\ dry\ weight$$

Statistical analysis
The data was subjected to analysis of variance (ANOVA) using GenStat 18th Edition. Fisher's Protected, Least Significance Difference (LSD) was used to compare treatment means at 5 % level of significance.

Results

Germination percentage
The germination responses of bean seeds pre-soaked in 60 ml. L^{-1} GA_3 solution after 48, 72, 96 and 120 h from soaking are shown on figure 1. At 48 h, germination percentage was highest for Nua45 (Nua GA, 10 %) seeds pre-soaked in GA_3 solution, while the untreated control (Nua) and the untreated Gloria (Gloria) were both low (3%, respectively). The germination percentage for the treated Gloria (Gloria GA) was zero. After 72 h, the treated Nua45 maintained the highest germination percentage (63 %), while the untreated Nua45 and untreated Gloria were 43 and 50 %, respectively. Germination of treated Gloria (Gloria GA) was the lowest (23 %). At 96 h, germination percentages of treated Nua45 was 100 % and the germination percentages of untreated Nua45 and the untreated Gloria seeds were 90 %, respectively. The germination percentage of the treated Gloria seeds was still the least (73 %). At 120 h, the germination percentages of the untreated Nua45 and untreated Gloria seeds were 93 and 97 %, respectively. The germination percentage of the treated Gloria seeds was 90%.

Rootlet length
The effect of soaking Nua45 and Gloria, bean seeds in 60 ml. L^{-1} gibberellic acid solution on rootlet length after 120 h from soaking is shown in figure 2. There were significant mean rootlet length differences between treatments ($p < 0.05$). The rootlet length of the seedling from treated Nua45 seeds (Nua GA) was significantly longer (5.29 cm) compared to the seedlings from untreated Nua45 seeds (Nua, 4, 12 cm), treated Gloria seeds (Gloria GA, 2.49 cm) and the untreated Gloria (Gloria, 2.86 cm) seeds. The rootlet length of the seedlings from untreated Nua45 seeds was significantly longer compared to both treated and untreated Gloria seeds. There were no significant rootlet length differences between the seedlings from treated and untreated Gloria seeds.

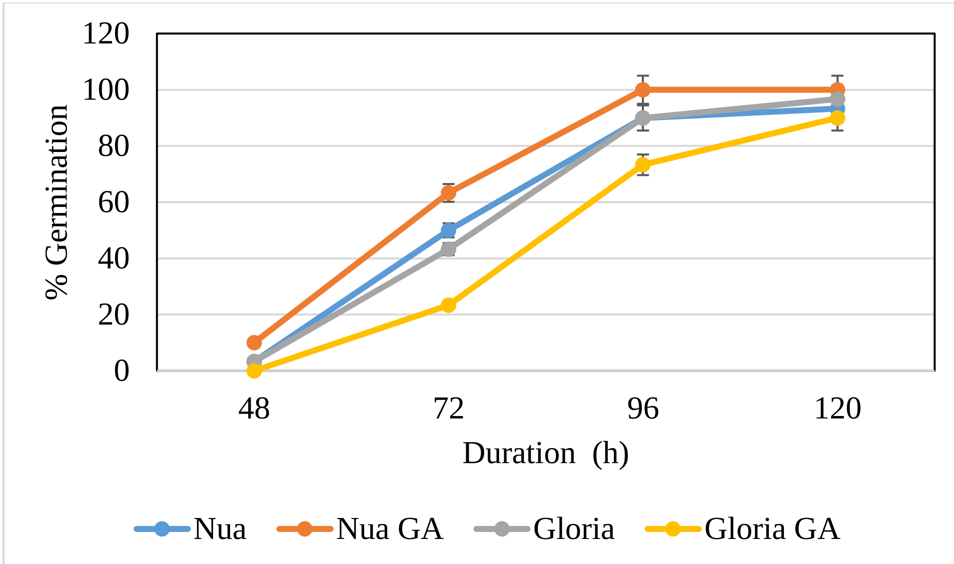

Figure 1: The effect of pre- soaking Nua45 and Gloria bean seeds in 60 ml L^{-1} gibberellic acid solution on germination percentage at 48, 72, 96 and 120 h, respectively.

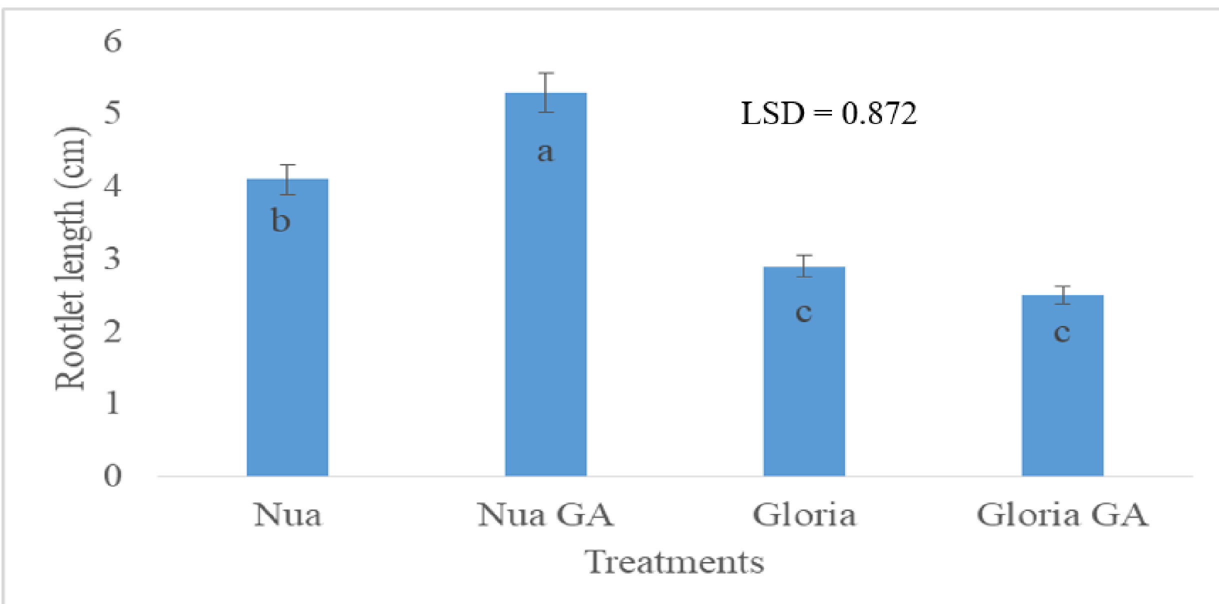

Figure 2: The effect of soaking Nua45 and Gloria bean seeds in 60 ml L^{-1} gibberellic acid solution on rootlet length after 120 h from soaking.

Seedling vigour index I (SVI I)

The effect of soaking Nua45 and Gloria bean seeds, in 60 ml L^{-1} gibberellic acid solution on seedling vigour index I (SVI 1) is shown in table 1. There were no mean SVI 1 differences between treatments ($p = 0.080$). However, the SVI I for treated Nua45 seeds (Nua GA, 42.6) was slightly higher compared to the untreated Nua45 (Nua, 27.3) seeds.

Percent emergence and seedling growth

Pre-soaking seeds of Nua45 and Gloria bean varieties in 60 ml L^{-1} gibberellic acid (GA_3) solution significantly ($p < 0.05$) affected root length (cm), shoot length (cm), dry weight (g) and seedling vigour index II (Table 2). However, there was no significant effect of pre-soaking these varieties in GA_3 solution on seedling emergency percentage (p = 0.121). Besides, the emergency percentage of treated Nua45 seeds was slightly higher (70 %) compared to untreated Nua45 seeds (60 %). Again, the emergency percentage of untreated Gloria seeds was slightly higher (80 %) compared to the treated seeds (60 %).

Table 1: The effect of soaking Nua45 and Gloria bean seeds, in 60 ml L^{-1} gibberellic acid solution on seedling vigour index I.

Treatment	Seedling vigour index I
Gloria	25.2
Gloria GA	27.2
Nua	27.3
Nua GA	42.6
P value	0.080
$LSD_{5\%}$	14.52

Table 2: The effect of pre-soaking seeds of Nua45 and Gloria common bean varieties in 60 ml L^{-1} gibberellic acid (GA_3) solution on emergency percentage, root length, shoot length, dry weight and seedling vigour index II.

Treatments	Emergency percentage (%)	Root length (cm)	Shoot length (cm)	Dry weight (g)	Seedling Vigour Index II
Gloria	80	35.1 a^	27.0 b	3.33 b	3.08 b
Gloria GA	60	14.4 b	27.2 b	4.17 a	4.17 a
Nua	60	13.7 b	28.5 b	2.34 b	2.25 c
Nua GA	70	24.2 ab	46.7 a	4.10 a	3.70 ab
P value	0.121	0.040	0.023	<.001	0.002
LSD	16.03	15.50	13.24	0.687	0.727

^*Means with different letters in the same column are significantly different at 5 % level of significant.*

The root length of seedlings from the untreated Gloria seeds were significantly longer (35.1 cm) compared to seedlings from the treated Gloria seeds (14.4 cm). However, the length of the roots of seedlings from the untreated Gloria seeds and treated Nua45 seeds (24.2 cm) were not significantly different. Besides, the root length of seedlings from the treated Nua45, untreated Nua45 and treated Gloria seeds were not significantly different. It could be noted that pre-soaking in 60 ml L^{-1} GA_3 solution had no effect on root length of Nua45 but inhibit root elongation in Gloria. Besides, pre-soaking in GA_3 solution had no effect on shoot growth of Gloria but promote shoot elongation in Nua45. There was no shoot length difference between seedlings from treated and untreated Gloria seeds. However, the seedlings from treated Nua45 seeds had significantly taller shoots (46.7 cm) compared to the seedlings from untreated Nua45 (28.5 cm) seeds. Shoot length of the seedlings from the treated and untreated Gloria seeds were significantly shorter (27.2 and 27.0 cm, respectively) compared to seedlings from treated Nua45 seeds, but not significantly different from the seedling of untreated Nua45 seeds. The dry weight of the seedlings from treated Nua45 seeds was significantly high (4.10 g) compared to seedlings from untreated Nua45 seeds (2.34 g). Again the dry weight of the seedlings from the treated Gloria seeds was significantly high

(4.17 g) compared to seedlings from the untreated Gloria seeds (3.13 g). However, the dry weight of seedlings from treated Nua45 seeds and treated Gloria seeds were not significantly different. Again, the dry weight of the seedlings from the untreated Nua45 seeds and untreated Gloria seeds were not significantly different. It could be noted that, pre-soaking seeds of both Nua45 and Gloria common bean varieties have improved their seedlings dry weight. In terms of seedling vigour index II, the seedlings from the treated Gloria had significantly high SVI II (4.17) compared to seedling from untreated Gloria seeds (3.08). Again, seedlings from treated Nua45 seeds had significantly high SVI II compared to seedling from untreated Nua45 seeds. It can be noted that pre-soaking seeds of both Nua45 and Gloria common bean varieties improves their seedling vigour index II.

Discussion

Pre-soaking Nua45 and Gloria common bean seeds in 60 ml L^{-1} GA_3 solution had opposite effects on seed germination and early seedling growth of the two varieties. Pre-soaking the seeds of Nua45 increased the rate of germination and pre-soaking Gloria seeds reduced the rate of germination. Nua45 seeds pre-soaked in GA_3 solution completed germination after 96 h (100 %) from soaking. By this time, the untreated seeds of the same variety were still germinating. The germination percentage of the untreated Nua45 seeds was 90 % after 96 h and 93 % after 120 h. As for Gloria, the germination percentage of pre-soaked seeds was 73 % whilst that of the untreated seeds was 90 % at 96 h and 90 and 97 % at 120 h, respectively. These opposite effects of pre-soaking seeds in GA_3 solution on different common bean varieties could be attributed to genotypic differences. Taiz and Zeiger (2010) noted that different seeds produce different levels of gibberellins during germination. It could be assumed that Gloria seeds produce enough endogenous gibberellins to promote its germination and hence, exogenous gibberellins supplementation may increase gibberellins levels to excessive levels. Zanamwe (2019) noted that excessive levels of gibberellins may have negative effects on germination of seeds of some plants. The influence of genotype on the response of common bean varieties to plant hormones was also reported by Mohtashamı *et al*. (2016) on seeds of two red bean varieties, D81083 and KS31169, treated with salicylic acid (SA) and naphthalene acetic acid (NAA), where the effect of line was dominant in all measured characteristics except harvest index. In a study to stimulate lower stem elongation of common bean cultivars by gibberellic acid, different sensitivity of cultivars to GA_3 treatment was also reported (Pavlista *et al*., 2012). In that study, two common bean varieties, Matterhorn and Poncho, were pre-soaked in GA_3 at 62.5 to 16,000 ppm before planting. The height of the unifoliate and first trifoliate nodes showed maximum stimulation of stem elongation by 1000 ppm GA_3 for ‘Poncho’ and by 2000 ppm for ‘Matterhorn’ after 14 days from emergency. In the current study, Nua45 had the highest percentage of seeds that germinated as compared to Gloria regardless of whether or not GA_3 was applied (Figure 1). For each interval (48-120 h), Nua45 was found to be faster in germination, implying that it has inherent germination ability. The enhanced performance of Nua45 in the present study supports the works of Erol and Arslanoğlu, (2022) and Sharma and Jain, (2016); who also noted that some varieties have faster water uptake as well as faster mobilization of the reserves during germination. It could be hypothesised that Nua45 seeds mobilize stored reserves fast in response to pre-soaking in GA_3 solution compared to Gloria. Such characteristics could make Nua45 more advantageous where quick germination is important for the successful growing of common bean. However, by 120 h, all the treatments had germination percentages in the high range. It is therefore, noted that GA_3

enhances the initial rate of germination of Nua45 cultivar and suppressed the initial rate of germination of 'Gloria' seeds.

The opposite effect of pre-soaking seeds of Nua45 and Gloria bean varieties in GA_3 solution was also observed on rootlet elongation (Figure 2) and SVI 1 (Table 1). The rootlet length of seedlings from pre-soaked Nua45 seeds were significantly longer compared to seedlings of untreated Nua45 seeds. However, the rootlet length of seedlings of pre-soaked and untreated Gloria seeds were not significantly different. Though not significantly different, the SVI 1 of pre-soaked Nua45 seeds was slightly higher compared to the untreated seeds. These differential responses to GA_3 treatment were also recorded in other crops. In barley, significant root length and germination vigour differences among varieties; Samir, Amil, Aksad, Alkhayr and Shueae, treated with four gibberellic acid concentrations; 0, 50, 100, and 150 mg L^{-1}, were recorded (Mohammed and Baldwin, 2023). These results emphasize the influence of genotype on the effects of hormones on germination and seedling growth.

In the greenhouse study, pre-soaking Nua45 seeds in GA_3 solution improved seedling growth parameters, i.e., shoot length (cm), dry weight (g) and seedling vigor index II (Table 2). The seedlings of Nua45 pre-soaked in GA_3 solution had longer shoots, high dry weight and high SVI II compared to untreated Nua45 seedlings. These results demonstrated the ability of GA_3 to stimulate cell growth and hence improve stem elongation and overall seedling vigour. The shoot length of the seedlings from Nua GA_3 (treated Nua45) were significantly longer (46.7 cm) compared to the shoot length of Nua (untreated Nua45; 28.5 cm). This suggest that faster stem growth has been promoted by pre-soaking Nua45 seeds in GA_3 solution. Kaur *et al*. (2023) reported that the hormone gibberellic acid (GA_3) increased elongation of shoot cells making plants taller in mung beans. Although at different GA_3 doses, Pavlista (2012) also found increased shoot elongation on seedlings of Matterhorn and Poncho common bean varieties when the seeds were pre-soaked in GA_3 solution. The results of this study suggest that pre-soaking seeds of Nua45 bean seeds in GA_3 solution promotes rapid shoot elongation during early seedling growth stages. Increased shoot elongation during early seedling growth stages raises the nod bearing the first fruit, a feature that reduce yield loses where harvesting is done mechanically (Pavlista, 2012; Lanes et al., 2019). Again, seedling shoot elongation is useful in producing taller seedlings, a survival advantage in terms of capturing light. Generally, improved light capturing promotes efficient photosynthesis (Taiz and Zeiger, 2010). The positive effect of pre-soaking Nua45 bean seeds was also observed on dry weight. The pre-soaked Nua45 seedlings had high dry weight compared to the untreated Nua45 seedlings. Increase in dry weight indicates that more biomass was accumulated which suggest that pre-soaking Nua45 seeds in GA_3 promotes rapid accumulation of biomass. Previous studies also indicated that GA_3 increased dry matter in many crops (Al Sahil, 2016; Zhu *et al*., 2019; Marinho *et al*., 2021; Kaur et al., 2023; Mohammed, 2023). These results suggest that pre-soaking Nua45 bean seeds in GA_3 solution increase stem elongation, thereby enhancing photosynthetic efficient through increased light capturing and hence increased dry weight accumulation compared to the seedlings from the untreated control seeds.

The inhibitory effect of pre-soaking Gloria seeds in GA_3 solution demonstrated on seed germination and rootlet growth in the germination test was also observed on seedling root length in the greenhouse study. These findings are in contradiction to some previous studies which indicated that GA_3 promotes root development and root elongation in common bean (Jaques *et al*., 2019), mung bean (Panchal and Prajapati, 2019) and rye (Qin *et al*., 2022). Therefore, it could be hypothesized that Gloria seeds produce sufficient levels of gibberellins to promote germination and early seedling growth and hence exogenous applications may increase the levels to supra optimal level that cause negative effects such as poor seedling root growth. In a study to alleviate salt stress in germinating sweet sorghum, high levels of GA_3 (576 µM) was found to have significant negative effects on seed water uptake, cumulative germination, germination index, and length of germ and radicle; whereas the optimum level (288 µM GA_3) relieved salt stress and improved seed germination (Zhu et al., 2019). In the present study, GA_3 exerted a very strong inhibition on root elongation in Gloria suggesting that this variety is able to enhance root growth more greatly with no exogenous gibberellin supplement. Further studies including more varieties may elucidate these contrasting results.

Notwithstanding the negative effects of pre-soaking Gloria seeds in GA_3 solution on seedling root development and no effect on shoot length, pre-soaking seeds in GA_3 solution improved dry weight and seedling vigour index II of seedling from treated seeds compared to seedlings from untreated Gloria (Gloria) seeds (Table 2). This may suggests that pre-soaking Gloria seeds in GA_3 improves its dry weight and vigour even though the shoot was not affected and the root length was reduced. These results may suggest that the improvement of dry weight and SVI II by pre-soaking Gloria bean seeds in GA_3 could not be explained by shoot and root length. It could, therefore, be assumed that pre-soaking Gloria seeds in GA_3 solution may have affected other parameters such as leaf size, stem girth and leaf numbers that also contributes to the seedling's total dry weight. In a study to understand the effects of gibberellic acid on growth and yield of French beans, 30 to 90 ppm GA_3 applied 18 days after sowing significantly increased number of branches and leaves, leaf area, leaf area index (LAI), leaf dry matter and total dry matter at different growth stages (Noor et al., 2017). Increased dry weight and SVI II could be of important, especially to bean varieties such as Gloria, where development of seedling vigour could compensate for delays in root elongation.

Conclusion

It could be concluded that the effect of pre-soaking bean seeds in GA_3 solution on germination and early seedling growth vary with cultivar. Pre-soaking Nua45 improved seed germination, seedling vigour and early seedling growth. However, pre-soaking Gloria seeds in GA_3 solution decreased the rate of germination and early seedling growth. Besides, pre-soaking Gloria seeds in GA_3 solution increased seedling dry weight and seedling vigour index II.

Recommendation

It is, therefore, recommended that seeds of Nua45 be pre-soaked in GA_3 solution before sowing to improve germination and early seedling growth. It is not advised to pre-soak Gloria bean seeds in GA_3 solution before sowing for doing so may delay germination and early seedling growth. Future studies should, therefore, be aimed at delineating seeds of bean cultivars that respond positively to pre-soaking in GA_3 solution from those that do not show such benefits. Again, the seedling dry weight and seedling vigour index II improving effect of pre-soaking Gloria seeds in GA_3 solution without increasing root and shoot growth is difficult to explain and, hence, should be studied further. Furthermore, the effects of combination treatment of GA_3 and other plant hormones such as auxin and abscisic acid on germination and seedling growth of common beans should be investigated.

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