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Effects of osmo-priming on germination, growth and green pod yield of okra [*Abelmoschus esculentus* (L.) Moench] at Luyengo, Middleveld of Eswatini

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Abstract

Okra is a nutritious summer vegetable crop in Eswatini. However, it has slow and uneven germination. Seed pre-sowing treatment through osmo-priming can enhance the germination, growth and yield of okra. Thus, laboratory and field experiments were conducted at Luyengo, Middleveld of Eswatini in 2019/2020 cropping season to determine the effect of osmo-priming on germination, growth and yield of okra. Treatments included priming of seeds with Polyethylene glycol (PEG) concentration of 5%, 10%, 15%, and 20% and unprimed control. Completely randomized design was used for the laboratory experiment and randomized complete block design was used for the field experiment. Results showed significant ($p<0.01$) effect of seed priming on the germination index, mean germination time and final germination percentage of okra seeds. Significantly the highest germination index (5.2) and final germination percentage (66) were recorded in priming with 15% PEG. Similarly, seeds priming with 15% PEG resulted in significantly the highest number of leaves per plant (12.07), leaf area index (1.49), canopy height (120.9 cm), and number of branches per plant (8.13). Moreover, okra seeds primed in 15% PEG resulted in the highest pod length and total green pod yield (2009.8 kg ha^{-1}). Thus, it can be concluded that seed priming with 15% PEG is the most effective in improving the germination, growth and yield of okra in the study area.

Keywords: Germination index; Germination percentage; Okra; Osmo-priming; Polyethylene glycol

1. Introduction

Okra [*Abelmoschus esculentus* (L.) Moench] is a common vegetable crop grown under tropical and subtropical conditions. Being native to tropical Africa (extending from Ethiopia to the Sudan), it is valued vegetable in many countries [1]. Okra has tender delicious fruits and is a good source of essential vitamins (e.g., Vitamin C) and minerals such as calcium, phosphorus, magnesium and iron. It possesses high nutritive value, which is higher than tomatoes, eggplant and most cucurbits except bitter gourds [2]. Okra pods are a good source of flavonoid antioxidants like beta carotene, xanthein and lutein [3]. Okra is also valuable with regards to anti-carcinogenicity, human immunity promotion, ageing prevention and health-care [4].

However, the slow and uneven germination of okra seed is the main problem in its production [5]. The percentage of seed germination of okra is relatively low, due to occurrence of hard seededness [6]. The percentage of hardseedness varies among the cultivars with some cultivars not having hardseedness or having a low percentage of hard seeds that doesn't impose any impedance on their germination, whereas for other cultivars the high percentage of hard seeds does not allow them to germinate, or allows only for low germination percentage [7].

Seed priming is pre-sowing treatment used as a technique to enhance seed performance, notably with respect to rate and uniformity of germination, thereby improving seedling stand and enabling better crop establishment [8]. It is a

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simple, low cost and effective approach for early seedling growth and yield under stressed and non-stressed conditions. Priming triggers the synthesis or activation of some enzymes that catalyze the mobilization of storage reserves in seed, while endosperm weakens by hydrolase activities. Priming may also increase resistance to abiotic stresses such as drought [9].

There are various types of seed priming, in one type water penetrate freely into seed which is called hydropriming while in other type seed hydration is controlled. If controlled hydration is achieved through the addition of solute to water then it is called osmopriming or if a solid matrix is used to provide controlled seed hydration then it is called solid matrix priming [10]. Osmopriming strengthens the antioxidant system and increases seed germination potential, resulting in an increased stress tolerance in germinating seeds [11]. Osmopriming with polyethylene glycol (PEG) improves seed germination, emergence, and seedling establishment of several crops especially under stress conditions and also enhances general crop performance. For instance, improvements in germination and seedling establishment were noted for rice (*Oryza sativa* L.) under drought after seed osmopriming with PEG [12]. Similarly, osmopriming cumin seeds (−0.8 and −1.2 Mpa of PEG 6000 solution) accelerated seed germination to a largest extent and improved the germination rate and uniformity under drought stress [13].

Okra is an important short duration vegetable crop in Eswatini. However, the yield of the crop is low partly due to erratic and poor germination of the seeds. Sikhondze and Ossom [14] recommended hydro priming of okra seeds for 24 hours before planting. Similarly, Rahman et al. [15] reported maximum absolute growth rate of okra at -1.2Mpa osmotic potential with PEG-8000. Since the response of seed to priming is affected by priming duration [16], osmotic potential of priming solution [17], priming agent [18], oxygen supply to seed [19], and cultivars [7], there is a need to determine an appropriate concentration of priming medium for okra.

Thus, this study was undertaken to determine the effects of concentrations of polyethylene glycol (PEG) on germination, growth and green pod yield of okra.

2. Material and methods

2.1. Laboratory experiment

2.1.1. Treatments and the experimental design

The treatments consisted of four concentrations of Polyethylene glycol 400 (PEG 400), *i.e.* 5%, 10%, 15% and 20% and unprimed dry seeds. Completely randomized design with three replications for each treatment was used.

2.1.2. Experimental procedure

The experiment was conducted in the Agronomy laboratory of Crop Production Department which had an average temperature of 23 °C. The PEG was diluted in distilled water in the ratios of 5:95, 10:90, 15:85 and 20:80 to obtain 5%, 10%, 15% and 20% PEG concentrations, respectively. The seeds were soaked in 10 ML of different concentrations of PEG for 24 hours in an incubator adjusted at 25°C under dark condition. After priming, the seeds were rinsed with distilled water and surface-dried on moisture absorbent cotton sheet and dried to their near-original moisture content at room temperature. After drying, 50 seeds were put in each sterilized petri-dish with a diameter of 12 cm for the germination test. The treatments were assigned completely at random in the petri-dishes in three replications each. Counts of germinated seeds were made daily from 14:00-16:00 hours starting from the second day after putting the seeds in the petri-dishes until there was no further germination on day 12. Same amount of distilled water was applied to keep the seeds in the petri-dishes moist.

2.1.3. Data collected

Final Germination Percentage (FGP) was determined as described in ISTA [22].

$$FGP = \frac{Total\ number\ of\ normal\ seeds\ germinated}{Total\ number\ of\ seeds\ sown} \times 100$$

Similarly, the Germination Index (GI) and Mean Germination Time (MGT) were determined as described by Ellis and Roberts [23].

$$GI = \frac{No.of\ germinated\ seeds}{Days\ of\ first\ count} + \ldots + \frac{No.of\ germinated\ seeds}{Days\ of\ final\ count}$$

$$MGT = \frac{\Sigma\ (Dn)}{\Sigma n}$$

Where *n* is the number of seeds that germinated on day *D* and *D* is a number of days counted from the beginning of germination.

2.2. Field experiment

2.2.1. Site description

The field experiment was conducted at Luyengo, the University of Eswatini, Faculty of Agriculture, Crop production farm. Luyengo is located in the Middleveld agro-ecological zone of Eswatini, at longitude of 31.10° East and latitude of 26.334° south and has an altitude of 750 m above sea level [20]. The site has an average annual rainfall of 980 mm with most rain occurring between October and April. The mean annual temperature is 18 °C with average winter temperature of 15 °C and with average summer temperature of 27 °C. The average temperature and total rainfall during the growing season of December 2019 to April 2020 were 22.4 °C and 449.2 mm, respectively. The soil type of the experimental site is the Malkerns M set soil series clay loam to sandy loam *Oxisols* mostly with acidic soil pH [21].

2.2.2. Treatments and the experimental design

The treatments consisted of four concentrations of Polyethylene glycol 400 (PEG 400), *i.e.* 5%, 10%, 15% and 20% and unprimed dry seeds. Randomized Complete Block Design with three replications for each treatment was used for the experiment.

2.2.3. Experimental field management

The experimental field was ploughed and disked to a fine tilth with tractor and the plots were levelled manually. According to the design, a field layout was made and each treatment was assigned randomly to the experimental units within a block. The gross size of each plot was 3.6 m × 3.6 m (12.96 m^2) consisting of four rows in inter-row spacing of 90 cm and intra-row spacing of 25 cm. The outermost one row on both sides of each plot was considered as border and not used for data collection to avoid border effects. Thus, the net plot was 2 rows × 0.9 m × 3.6 m (6.48 m^2). After priming the seeds at their respective concentration of PEG, the seeds were dried to initial moisture content at room temperature and then three okra seeds were sown per planting station at a planting depth of about 2.5 cm. At planting, fertilizer 2:3:2(22), consisting of 6.3% N, 9.4% P and 6.3% K, was applied at the rate of 300 kg ha^{-1}. Limestone ammonium nitrate (LAN) containing 28% nitrogen was side dressed four weeks after emergence of okra plants at a rate of 200 kg ha^{-1}. Thinning to one plant per station was done three weeks after emergence. Weeds were controlled manually using hand hoe. As the experiment was a rain-fed, no supplemental irrigation was applied.

2.2.4. Data collected

The numbers of leaves were counted at 50% flowering stage from five randomly selected plants from each of the net plot and the number was averaged on per plant basis. The leaf area was determined using the cork borer method from three randomly selected plants per net plot at 50% flowering stage following the procedure described by Edje and Ossom [20] and the leaf area was averaged on per plant basis. Then, the leaf area index was determined by dividing the leaf area (cm^2) per plant by the ground area occupied by each plant (90 cm × 25 cm). The number of branches was determined by counting the branches on the main stem from three randomly taken plants from each net plot at last harvesting and was averaged on per plant basis. Canopy height was measured using a calibrated stake, measuring from the surface of the soil to the highest leaf subtended by the plant. Ten plants were picked at random from the net plot at the last harvesting stage and the height was averaged on per plant basis. Similarly, the length of pod bearing zone was determined by measuring the length from the point of beginning of the pod to the point where pod formation ends from randomly taken ten plants from the net plot and then the length was averaged on per plant basis.

The green pods from the net plot were harvested three times at a weekly interval. After each harvest, the lengths and widths of the ten randomly taken green pods from each net plot were measured using ruler and a Vernier caliper, respectively, and averaged on per plant basis. Yield of green pods per net plot was determined at each harvest. Then, the total green pod yield per hectare was determined by summed up the yield of all the three harvests per net plot and was expressed in kg ha^{-1}

2.3. Data analysis

Data from both experiments were subjected to analysis of variance using GenStat 15th Edition [24]. Significantly different treatment means were separated using the least significant difference (LSD) test at 5% level of significance.

3. Results

3.1. Germination characteristics

There was a highly significant ($p<0.05$) effect of priming with different concentrations of PEG on the germination index and final germination percentage of okra seeds (Table 1). Significantly the highest germination indices of 5.63 and 5.2 were recorded in priming the seeds with 5% PEG and 15% PEG, respectively (Table 1). Similarly, the highest final germination percentage (66) was recorded in priming with 15% PEG. In contrast, the lowest germination index (3.82) and final germination percentage (46) were recorded from the control (no priming) (Table 1).

The mean germination time was significantly ($p<0.05$) affected by priming with different concentrations of PEG (Table 1). The shortest mean germination time (4.69 days) was recorded for the control while the PEG concentrations significantly delayed the mean germination time ranging from 6.04 days to 6.79 days (Table 1).

Table 1 Effects of priming with different concentrations of PEG on germination characteristics of okra seeds

PEG concentration	Germination index	Final germination %	Mean germination time (days)
Control (no priming)	3.82b†	46.0c	4.69b
5% PEG	5.63a	64.7ab	6.04a
10% PEG	4.18b	56.0b	6.13a
15% PEG	5.20a	66.0a	6.79a
20% PEG	4.27b	60.0ab	6.70a
LSD (0.05)	0.699	9.11	1.14
Significance	**	**	*

LSD (0.05) = Least Significant Difference at 5% level; †Means in columns followed by the same letters are not significantly different at 5% level of significance according to LSD test.; * And ** = Significant at 5% and 1% level of probability, respectively

3.2. Growth parameters

3.2.1. Number of leaves, leaf area index and number of branches

The number of leaves and leaf area index per plant at flowering were significantly ($p< 0.05$) affected by the priming treatments (Table 2).

Table 2 Effects of priming with different concentrations of PEG on growth parameters of okra

PEG concentration	Number of leaves per plant	Leaf area index	Number of branches per plant
Control	9.53b†	1.05b	5.33b
5% PEG	9.47b	1.04b	5.33b
10% PEG	11.13a	1.27ab	5.67b
15% PEG	12.07a	1.49a	8.13a
20% PEG	9.53b	1.08b	5.33b
LSD (0.05)	1.527	0.240	0.908
Significance	*	*	**

LSD (0.05) = Least Significant Difference at 5% level; †Means in columns followed by the same letters are not significantly different at 5% level of significance according to LSD test; * And ** = Significant at 5% and 1% level of probability, respectively.

The highest number of leaves (12.07) was recorded in priming with 15% PEG and it was statistically at par with priming in 10% PEG (11.13). Similarly, significantly the highest leaf area index (1.49) and number of branches per plant (8.13) were recorded in priming with 15% PEG followed by priming in 10% PEG. In contrast, the other concentrations and the control gave significantly lower number of leaves, leaf area index and number of branches of okra (Table 2).

3.2.2. Canopy height and length of pod bearing zone

The canopy height at the third harvest was highly significantly (P<0.05) affected by the priming treatments (Figure 1). Significantly the highest canopy height (120.9 cm) was recorded in priming with 15% PEG while the other concentrations and unprimed control had significantly lower canopy height. On the other hand, the effect of priming with PEG had no significant effect on length of pod bearing zone of okra (Figure 1). The length of pod bearing zone ranged from 29.5 cm in priming with PEG at 5% to 33.20 cm in priming with 15% PEG (Figure 2).

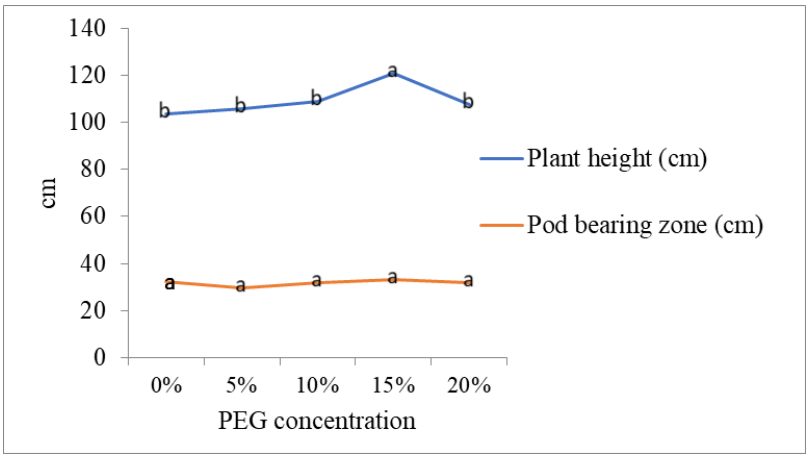

Figure 1 Canopy height and length of pod bearing zone of okra in response to priming with different concentrations of PEG

Means in lines followed by the same letter are not significantly different at 5% level of significance according to Least Significant Difference (LSD) test.

3.3. Yield components and yield

3.3.1. Pod length

There was highly significant (P<0.01) effect of priming with PEG on the length of pods in first and second harvests (Figure 2). Priming with 15% PEG resulted in significantly the highest pod length of 11.73 cm and 13.27 cm at first and second harvests, respectively (Figure 2).

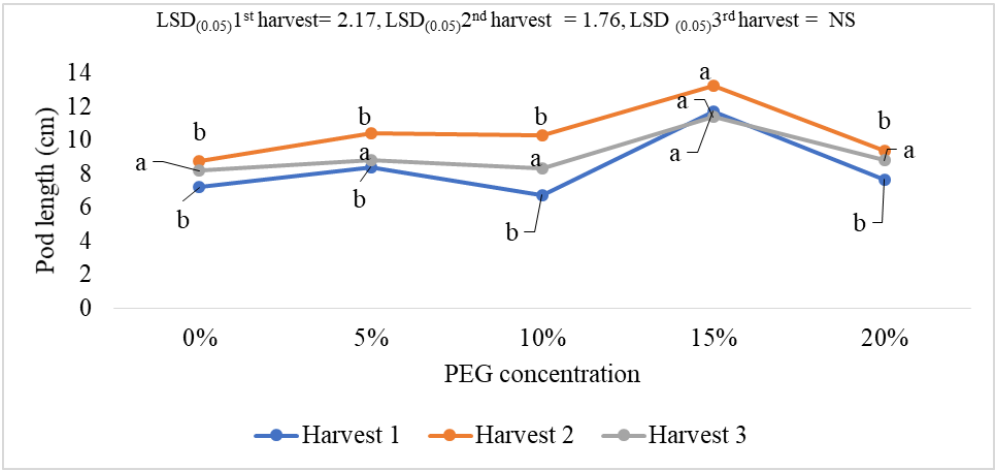

Figure 2 Average pod length (cm) of okra from the first to third harvests in response to priming with different concentrations of PEG

In contrast, the other treatments gave significantly lower pod lengths at both harvests. In the second harvest, the unprimed control had the lowest pod length of 8.73 cm. On the other hand, the effect of priming with PEG had no significant effect on pod length at third harvest (Figure 2).

However, priming with 15% PEG had the highest pod length of 11.4 cm (Figure 2). In general, pods in the second harvest had higher length than in the first and the third harvest.

Means in lines for same harvest followed by the same letter are not significantly different at 5% level of significance according to Least Significant Difference (LSD) test.

3.3.2. Pod width

There was no significant difference among the pod widths obtained from the first to the third harvests. In general, the pod width ranged from 2.1 to 2.4 cm (Figure 3). Priming with 15% PEG and the control resulted in relatively higher pod widths at all the three harvests as compared to the other treatments (Figure 3).

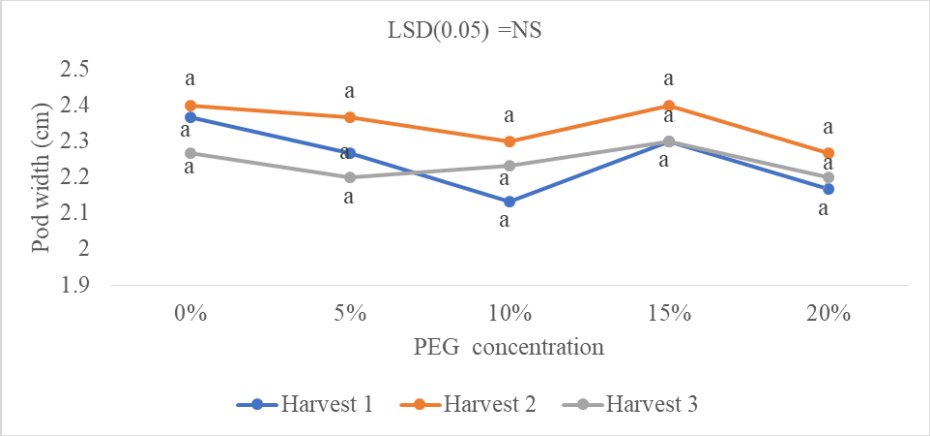

Figure 3 Average pod widths (cm) of okra from the first to third harvests in response to priming with different concentrations of PEG

Means in lines for same harvest followed by the same letter are not significantly different at 5% level of significance according to Least Significant Difference (LSD) test.

3.3.3. Green pod yield

There were no significant differences among the treatments in pod mass at all the three harvests (Figure 4).

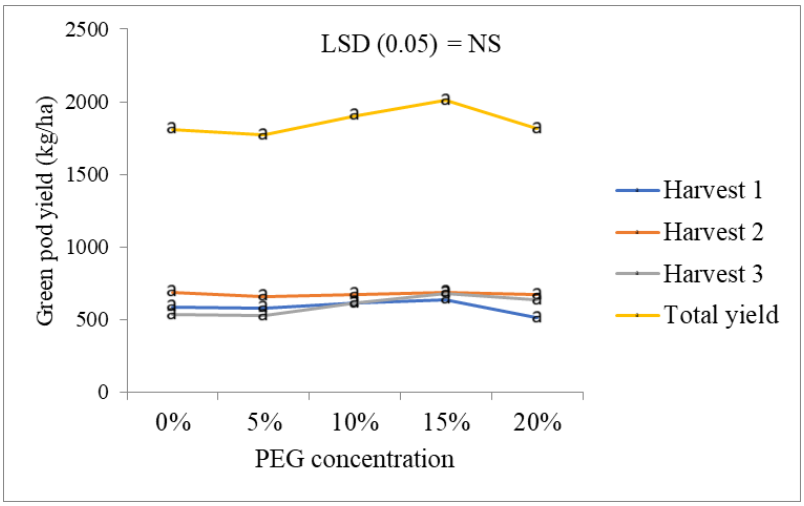

Figure 4 Average green pod yield from the first to the third harvest and total green pod yield of okra in response to priming with different concentrations of PEG

The pods mass ranged from 511 kg ha^{-1} with priming in 20% PEG at first harvest to 690.7 kg ha^{-1} with priming in 15% PEG at the second harvest (Figure 4). In general, higher pods yield was obtained at the second harvest. Likewise, different priming concentrations of PEG had no significant effect on the total green pod yield of okra (Figure 4). However, plants from seeds primed in 15% PEG had the highest total green pod (2009.8 kg ha^{-1}) from the three harvests followed by 10% PEG (1904.2 kg ha^{-1}) (Figure 4).

Means in lines for same harvest and total yield followed by the same letter are not significantly different at 5% level of significance according to Least Significant Difference (LSD) test.

4. Discussion

4.1. Germination characteristics

Priming of okra seeds with 15% PEG significantly increased the germination index and final germination percentage of okra seeds (Table 1). The possible reason for improved germination with priming might be synthesis of proteins and leaching of growth inhibitors [25], repair of deteriorative DNA in seeds and activation of antioxidant enzymes which lower peroxidation in seeds. Moreover, it has been reported that seed priming enhances the production of the enzyme α-amylase which plays a crucial role in starch mobilization and provides the embryo with carbohydrates for respiration during germination and seedling growth [26]. In line with this result, Rahman *et al.* [15] reported that priming with PEG improved percent germination of okra seeds as osmotic potential was lowered from 0 to -1.2 Mpa while further lowering osmotic potential to -1.6 Mpa and below adversely affected germination. Similarly, Zhang *et al.* [27] reported that seed priming with PEG was effective in improving seed germination and seedling establishment of sorghum under adverse soil moisture conditions through strengthened antioxidant system and increased osmotic adjustment, likely resulting in increased stress tolerance. In contrast, priming okra seeds with PEG was not effective in reducing mean germination time in this study which is in agreement with the result reported by Rahman *et al.* [15].

4.2. Growth parameters

4.2.1. Number of leaves, leaf area index and number of branches

The highest number of leaves and leaf area index per plant were recorded in priming the okra seeds with 15% PEG (Table 2) which might be due to uniform emergence and better seedling vigor and growth of the primed seeds. In agreement with this result, Shah *et al.* [28] reported that okra seeds primed for 24 h either in diammonium phosphate (DAP) or single super phosphate (SSP) gave higher number of leaves. Likewise, Hegazi [29] obtained higher number of leaves and leaf area per plant of okra with priming in Na_2HPO_4 as compared to priming in $MgSO_4$, KCl, water and unpriming. Similarly, priming with 15% polyethylene glycol produced significantly the highest number of branches (Table 2) which could be due to higher leaf area index resulting in higher photosynthesis and thereby partitioned to more number of branches. In consistent with this result, Hardeep *et al.* [30] reported that seed priming with 5% and 10% PEG produced maximum number of nodes and fruiting nodes of okra on main stem as compared to the unprimed seed. Ullah *et al.* [31] also reported that priming with micronutrients increased number of primary branches per plant and number of nodes and fruiting nodes on main stem in raya (*Brassica juncea*).

4.2.2. Canopy height and length of pod bearing zone

Seed priming with 15% PEG produced the highest canopy height and pod bearing zone of okra (Figure 1). The increase in canopy height and pod bearing zone in seeds primed with PEG might be due to enhanced water intake that promoted early establishment and vegetative growth. In agreement with this result, Rahman *et al.* [15] reported that okra plants grown from seeds primed with PEG or Mannitol solutions at 0 to -1.2 Mpa osmotic potential, had attained maximum canopy height while priming seeds with solution having osmotic potential of -2 Mpa or lower had reduced the canopy height. Arif *et al.* [32] also reported enhanced absolute growth rate and crop growth rates with increase in PEG concentration from 0 to 300 g PEG L^{-1} water and thereafter decreased.

4.3. Yield components and yield

4.3.1. Pod length and pod width

Seed priming with 15% PEG produced the highest pod length and width (Figures 2 and 3). The higher pod length and width with priming in 15% PEG could be due to better seedling vigor and growth which ultimately partitioned to larger pods. In agreement with this result, Hardeep *et al.* [30] obtained higher fruit length and fruit width of okra from seeds

primed with 5% and 10% PEG than hydro-priming. Similar results were reported by Saikia *et al.* [33] who obtained larger ear production in wheat with osmopriming (10% PEG).

4.3.2. Green pod yield

Plants from seeds primed in 15% PEG produced the highest green pod yield (Figure 4). The higher pod yield might be due to enhanced seedling vigor, improved vegetative and reproductive characters, which ultimately contributed to higher yield. Moreover, primed seeds are developmentally more advanced than dry seeds, resulting in a 'head start of germination' [34]. As a result, seedlings from primed seeds have more developed roots before the common limiting factors such as declining soil moisture, crust formation and/or high salinity prevent successful emergence. In agreement with this result, Rahman *et al.* [15] obtained maximum fruit yield (14.7 t ha^{-1}) of okra with priming in PEG at osmotic potential of -1.2 Mpa while the minimum yield (12.4 t ha^{-1}) was recorded for unprimed seeds. Likewise, Hardeep *et al.* [30] reported that okra seed priming with 5% PEG for 24 h duration gave better fruit yield and biochemical quality parameters by tolerating adverse environmental effects

5. Conclusion

Priming okra seeds with 15% PEG improved the germination characteristics, growth parameters, yield components and green pod yield of okra. Thus, priming okra seeds in 15% PEG for 24 hours can be used to increase the productivity of okra in the study area. However, to reach at a conclusive recommendation, the experiment has to be repeated over more years with inclusion of more priming treatments and durations to account for seasonal variations in weather variables.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare that they have no conflicts of interest.

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