DIFFERENT RESPONSES OF PREEMERGENCE AND EARLY SEEDLING GROWTH TO PLANTING DEPTH BETWEEN VEGETABLE SOYBEAN AND GRAIN SOYBEANS

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ABSTRACT

Planting depth can cause nonuniform emergence and poor field stands. There have been no investigations to compare the planting depth on field emergence between vegetable soybean and grain soybean [Glycine max (L.) Merr.]. This study examined the effect of planting depth on preemergence and seedling emergence in growth chamber conditions using one vegetable soybean and one grain soybean cultivar. The hypocotyl and radicle length in the vegetable soybean were significantly longer than that of the grain soybean at emergence, while the hypocotyl and radicle diameter in the vegetable soybean were significantly larger than that of the grain soybean during emergence period irrespective of planting depth. The weight of hypocotyl + radicle in the vegetable soybean was significantly greater than that of the grain soybean during emergence period irrespective of planting depth and days after planting, but deeper planting depth reduced cotyledon weight in the vegetable soybean strongly at emergence. As planting depth increased from shallow (1-cm) to deep (5-cm), emergence declined. However, the grain soybean seed consistently emerged better than the vegetable soybean seed. Emergence of both the grain soybean seed and the vegetable soybean was > 65% until planting depth increased to 3-cm, while the vegetable soybean seed had the lowest emergence (< 30%) at the deepest (5-cm) level. The 3-cm planting depth had no effect on the emergence of both the grain soybean and the vegetable soybean. The vegetable soybean was more susceptible to deeper planting depth than the grain soybean.

Key words: Edamame, Hypocotyl, Radicle, Seed germination.

INTRODUCTION

Planting seed quality, seedbed conditions, seedling emergence, and planting rate combine to determine plant population, which is often related to final yield. Seed germination and preemergent seedling growth through soil is critical in establishing even seedling emergence and a successful population, and thus high yield of soybean (Helms et al., 1996; Wheeler and Ellis, 1992). Emergence responses to seedbed conditions have previously been examined in normal field conditions (Rathore et al., 1981; Halmer and Bewley, 1984; FinchSavage and Pill, 1990). Though seed purity, soil texture, temperature and soil moisture content influence germination and emergence, planting depth is one of the main factors influencing growth of soybean seedling (Qiu et al., 2010). Onwueme and Sinha (1991) showed that the planting depth of soybean ranges from 2.5 to 5.0 cm. In loose (sandy) soil texture seed can be planted deeper, while in heavy clay soil seed should be planted shallow. However, Perez-Bidegain et al. (2007) indicated that the soybean yield varied at different planting depths, and highest yield could be gained by planting at 3cm depth. These results were mostly based on grain soybean (small-seeded field type soybeans), and examined in prevailing field conditions.

Vegetable soybean is a special type soybean with larger seed size, pleasant flavor harvested at R6-R7 stage when seeds are immature and pods are not turning yellow (Zhang et al. 2010). Though there is little or no genetic or biochemical difference

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between the vegetable soybean and grain soybean, we hypothesized the larger seed size, hypertrophic cotyledons, and weaker hypocotyls in vegetable soybean might influence its emergence under different planting depths. However, edamame growers often follow planting depth made for grain soybean, and very few attempts have been documented for optimum planting depth of vegetable soybean. The objective of this work was to quantitatively examine the effects of planting depth on preemergence and early seedling growth between a vegetable soybean and a grain soybean in controlled environments (growth chamber) and to provide a reference for vegetable soybean production.

MATERIALS AND METHODS

Growth chamber experiment was conducted from November 2011 through February 2012 to evaluate the effect of planting on soybean seedling emergence. One larger seed size vegetable soybean cultivar No.1 Edamame CAS and one grain soybean cultivar Northup King S19-V2 were used in the experiments. All seed lots were stored at 10°C before use. The standard germination (SG) test (Association of Official Seed Analysts, 2000) (4x50 seeds at 20/30°C for 7 d) was conducted before or after planting all experiments with standard germination of 98%. The soil used was taken from the surface A horizon at the University of Massachusetts Agricultural Experiment Station Farm in Deerfield, MA (42°N, 73°W), and was air dried, and sieved to a particle size of < 2 mm. The soil type was a Hadley fine sandy loam (coarse-silty, mixed, nonacid, mesic a Typic Udifluvent). Equal volume (weight) of soil was first put into containers, watered to make it compacted, and then restored to a soil moisture content of 60%. Following planting, the containers were not watered again. Five seeds were planted on each pot container at 1cm, 2cm, 3cm, 4cm and 5cm planting depth using a randomized complete block design with 15 replications (each container was an individual plot [replication]) and then all pots were put into growth chamber (Percival, Model 1-35L VL, Iowa, U.S.A.) at a day/night temperature 15°C/10°C, humidity 50%, lighting period 12/12 hours. Weights of hypocotyl + radicle and cotyledon 3, 6, 9, 12 days after planting were determined, while the diameter and length of hypocotyl and radicle were measured 6, 9, 12 days after planting, and the emergence rate at different planting depth was counted at 12 and 15 days. At each sampling date, three pots were measured, representing three replicates. Seedlings were counted as normal seedlings when one or two cotyledons were free of the soil surface, and as abnormal seedlings when cotyledons were either missing or had not emerged (Stage VE, Fehr and Caviness, 1977). Fresh weight of cotyledon and hypocotyl was measured. Pregerminated seeds that had grown no further after planting were also included with abnormal seedlings. No indication of radicle emergence from the seed (Association of Official Seed Analysts, 1992) was determined as dead seeds. The diameter of hypocotyl was measured at the jointing part between cotyledon and radicle while the diameter of radicle was measured at uppermost position of the root. Figures were drawn by Sigma Plot2000, and statistical data were analyzed by SPSS17.0.

RESULTS AND DISCUSSION

Changes of length in hypocotyl and radicle after planting: The hypocotyl length in the vegetable soybean was significantly longer than that of the grain soybean on the 6th day after planting irrespective of planting depth, and only significantly longer on the 9th day after planting at 1-cm, 2-cm, 3-cm and 4-cm planting depth (p> 0.05, Fig. 1). There was no difference between the vegetable soybean and the grain soybean on the 9th day after planting at 5-cm planting depth, and at all planting depths on the 12th day after planting. Radicle length in the vegetable soybean was significantly longer than that of the grain soybean at 1-cm, 2-cm and 5-cm planting depth on the 6th day after planting, and at all planting depths on the 12th day after planting. Radicle length in the vegetable soybean was significantly longer than that of the grain soybean at 1-cm, 2-cm and 5-cm planting depth on the 6th day after planting, and only at 1-cm, 2-cm planting depth on the 9th day after planting (p> 0.05, Fig. 2). The radicle length in the grain soybean was significantly longer than that of the vegetable soybean at 4-cm and 5-cm planting depth on the 9th day after planting. Though radicle length in the vegetable soybean was significantly longer than that of the vegetable soybean at 4-cm and 5-cm planting depth on the 9th day after planting. Though radicle length in the vegetable soybean was still significantly longer than that of the grain soybean on the 12th day after planting at 1-cm planting depth, no differences were found between the two soybean types among other planting depths.

Changes of diameter in hypocotyl and radicle after planting: The diameter of hypocotyl in the
vegetable soybean was significantly larger than that of the grain soybean during emergence period irrespective of planting depth (p>0.05, Fig. 3). The diameter of hypocotyl increased with the increase in planting depth from 1 cm to 5 cm on the 6th, 9th and 12th day after planting for the vegetable soybean and only on the 12th day after planting for the grain soybean. The diameter of hypocotyl in the grain soybean increased only from 1 cm to 3 cm planting depth and then declined from 4 cm to 5 cm planting depth on the 6th and 9th day after planting. The general trend for the vegetable soybean was the deeper the planting depth, the larger the diameter of hypocotyl. At 5 cm planting depth, the diameter of hypocotyl in the vegetable soybean was 92.6%, 40.9% and 7.2% larger than that of the grain soybean on the 6th, 9th, and 12th day after planting respectively.

Similar results were only observed for diameter of radicle on the 6th day after planting with significant difference between the vegetable soybean and the grain soybean at all planting depths (p>0.05, Fig. 4). While the diameter of radicle in the vegetable soybean was only significantly larger than that of the grain soybean at 1-cm and 2-cm planting depth on the 9th day after planting and 1-cm planting depth on the 12th day after planting (Fig. 2). There was no significant difference in the diameter of radicle between the vegetable soybean and grain the soybean from 3-5cm planting depth on the 9th and 12th day after planting.
Changes of weight in hypocotyl + radicle/cotyledon and emergence rate after planting:
The weight of hypocotyl + radicle in the vegetable soybean was significantly greater than that of the grain soybean during the emergence period irrespective of planting depth and days after planting (Fig. 5). The maximum weight of hypocotyl + radicle was found at 5-cm planting depth on all observed days after planting for edamame, but was found at the 3-cm planting depth on the 3rd, 6th and 12th day after planting and the 4-cm planting depth on the 9th day after planting for the grain soybean. Cotyledon weight in the vegetable soybean was also greater than that of the grain soybean under different planting depth, but deeper planting depth strongly reduced cotyledon weight in the vegetable soybean on the 3rd day after planting (Fig. 6). Emergence rate was significantly affected by planting depth (p>0.05, Fig. 7). The deeper the planting depth, the lower the emergence rate was. The emergence rate of the vegetable soybean was more affected by planting depth than that of the grain soybean. The 3-cm planting depth was the most appropriate depth for both the grain soybean and the vegetable soybean planting. At 4-cm and 5-cm planting depth, the vegetable soybean emergence rate was 16% and 35% lower than that of the grain soybean.

Planting depth effect on emergence has been extensively studied with a range from 2.5 to 5.0 cm in grain soybean (Halmer and Bewley, 1984; Finch-Savage and Pill, 1990; Onwueme and Sinha, 1991). In present studies, as the planting depth increased from shallow (1cm) to deep (5cm) the emergence rate declined gradually, and the emergency rate of
the vegetable soybean dropped faster than that of the grain soybean. Thus, when planting soybean seeds into deeper seedbed conditions, grain soybean seed would have an advantage and may be able to break through the surface layer while vegetable soybean seed may not.

The surprising results were that 3-cm planting depth had no effect on the emergence between grain soybean and vegetable soybean, however deeper or shallower than 3-cm planting depth greatly reduced emergence in vegetable soybean than that of grain soybean. Qiu et al. (2010) indicated that the soybean yield varied at different planting depths, and highest yield could be gained by 3cm depth. The deeper planting depth imposed a time disadvantage on the developing seedlings as was demonstrated in winter wheat (Triticum aestivum L.) by Lafond and Fowler (1989), who found that increased planting depth increased the time to emergence, resulting in poorer seedling development. Slow emergence in corn (Zea mays L.) was also noticed by Stewart et al. (1990) to predispose the crop to disease and adverse environmental conditions. In this study, the vegetable soybean was relatively more susceptible to planting depth than the grain soybean, and 3-cm planting depth was acceptable depth for both types of soybean.
Dicotyledonous species with epigeal emergence may encounter considerable resistance as the large cotyledons are pushed through the soil crust, which prevented emergence or severely damaged the hypocotyls or cotyledons and more in the vegetable soybean in this study. Rathore et al. (1981) showed small seeds tended to imbibe and germinate more rapidly, which allowed the seedlings to emerge sooner than those from large seeds and before crust strength was high enough to prevent emergence. In the present experiment, the seed size of the vegetable soybean was larger than the grain soybean, and the vegetable soybean had a longer, wider hypocotyl and heavier cotyledon than that of the grain soybean, this might be responsible for a reduced emergence at deeper planting depth compared to the grain soybean, suggesting that difference in seed size influenced soybean seedling emergence. It is entirely possible that a planted seed will germinate, yet still fail to emerge from the soil. The question therefore arises as to what is more important when determining causes for poor emergence in soybean: failure to germinate, or failed postgerminative growth? The pathogenicity of soilborne fungi such as Pythium, Fusarium, Rhizoctonia and Phytophthora spp has been implicated in reduced emergence of soybean seedlings (Pieczarka and Abawi, 1978; Schlub and Lockwood, 1981; Schlub et al., 1981). Soil and environmental conditions were identical in growth chamber experiment, thus pathogenicity of soilborne fungi could be excluded. However, though the standard germination rate was around 98% in the present studies, emergence rate was only between 30-40% at 5-cm planting depth. Therefore, progressive decline of seed vigor occurred during germination processes due to abnormal seedlings leading to total loss of viability. Delouche (1974) concluded that the germination test is an insensitive and misleading measure of soybean seed quality because it focuses primarily on the final consequence of deterioration and does not adequately take into account the very substantial loss in performance potential that can and does occur before germination capacity is lost. Egli and TeKrony (1995, 1996) indicated that soybean seeds with high vigor would provide adequate field performance under a wide range of seedbed conditions. However, though seed quality tests should relate to field emergence, we found deeper planting depth greatly reduced cotyledon weight more in the vegetable soybean than that of the grain soybean, suggesting planting depth imposed an earthly soil stress to the vegetable soybean seed to deteriorate much more rapidly than in the grain soybean. Thus, it was not surprising that the vegetable soybean in this experiment had a higher percentage of abnormal and dead seeds following a deeper planting. Rathore et al. (1981) monitored soybean seedling development in compacted, crusted soils and found that the hypocotyls became swollen and brittle, and often collapsed at the stress point between the cotyledons, producing an abnormal seedling. We also observed swollen hypocotyls in abnormal emerged seedlings and in germinated seedlings that did not emerge for vegetable soybean (data not shown). Therefore, the vegetable soybean emergence capacity was lower than the grain soybean, for this reason, a shallow sowing depth should be used with vegetable soybeans.

In summary, increases in planting depth reduced soybean seedling emergence. The vegetable soybean was more susceptible to deeper planting depth than the grain soybean. The 3-cm planting
depth resulted in the same seedling emergence for both types of soybean. Dead seeds occurred more with deeper planting depth in the vegetable soybean seed than in the grain soybean seed. Planting depth can be included in the list of the soil variables that can severely reduce soybean seedling emergence. The failure of emergence of normal seedlings as planting depth increased was primarily a function of germination failure (dead seeds) or germinated seedlings that were unable to break through the soil surface. It would be advantageous to plant vegetable soybean shallower than grain soybean at recommended seeding rates to achieve adequate seedling emergence and plant populations.

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