Soil physical conditions that limit chickpea emergence with particular reference to the High Barind Tract of Bangladesh

Wendy Vance[A], Richard Bell[A] and Chris Johansen[A]

[A]School of Environmental Sciences, Murdoch University, Murdoch, WA, Australia, Email w.vance@murdoch.edu.au, r.bell@murdoch.edu.au, cjo41802@bigpond.net.au

Abstract

Sowing of chickpea in the heavy textured soils of the High Barind Tract of Bangladesh with minimum tillage technology aims to increase the timely planting of large areas during a relatively short sowing window before soil water limits germination and emergence. However, the seedbed conditions into which chickpea is sown needs to be better quantified, so that limiting factors which affect germination and emergence can be identified. The soil physical characteristics of importance are soil water, strength and aeration. Growth cabinet studies have identified the fastest germination and emergence of chickpea to be in soils which have gravimetric water contents of 17 to 18 %, at soil water contents above and below this germination and emergence are delayed. Field experiments in Bangladesh have been monitored to determine in-field conditions at sowing. These field and laboratory experiments will be used to quantify the soil physical properties which limit the germination and emergence of chickpea in the HBT of Bangladesh.

Key Words

Germination, minimum tillage, soil water, Desi type.

Introduction

Chickpea (*Cicer arietinum* L.) crops in the High Barind Tract (HBT) of Bangladesh are grown mainly on residual soil moisture after rainy season rice and are subject to a range of stresses which may result in poor germination, emergence and stand establishment. After harvest of the rice crop, the region has high evaporation and temperatures which result in rapid loss of surface soil moisture, even though subsurface layers retain high soil water content. This results in sub-optimal surface soil water conditions for germination and emergence of chickpea seed. In the HBT it is important that chickpea seeds germinate and emerge quickly before the surface soil dries, such that a vigorous root system develops to support adequate nodulation and access soil moisture at depth.

The soil physical conditions of aeration, temperature, water content and strength affect the germination and emergence of a seed. These soil physical conditions are dependent on properties such as particle size distribution and bulk density which influence pore size distribution and aggregate size. These soil physical properties affect seed germination by controlling the seed-soil contact, water holding capacity and aeration. The seed water potential, soil water potential and the seed-soil interface are important factors in the initial water uptake phase required for seed germination (Hadas 2004). During the period from germination to emergence, when the seeds continue to require water and oxygen, and utilize their seed reserves for nutrients (Baker 2006) may be the critical period for successful chickpea emergence in the HBT due to the accelerated drying of the surface soil.

Previous research in a Vertisol soil, has determined the soil water contents at which emergence of Desi type chickpea seeds becomes limited. The volumetric water content at which chickpea failed to emerge was less than 20 % (Saxena 1987). This was a soil reported to have a field capacity of 34 % and wilting point of 19 %. Hosseini *et al.* (2009) found that as soil water content decreased to 50 and 25 % of field capacity the time to chickpea emergence (both Kabuli and Desi types) increased and early growth was suppressed.

Surface soils (0 -15 cm) in the HBT have been reported to have high silt and sand contents (up to 40 % of each), and have bulk densities between 1.5 and 1.6 g/cm^3 (Ali 2000). These two characteristics of soil in the HBT lead to a seed bed which is not optimum for chickpea germination or emergence in combination with an environment which quickly dries the surface soil after planting. In addition to soil physical constraints inherent in HBT soil, the development of new minimum tillage techniques adds another dimension to the management of these soils during the sowing of chickpea. The soil physical conditions in the slots of disturbed soil may limit the emergence of the seed: if there is inadequate seed coverage by the soil; if the soil covering the seed is not of an appropriate tilth; if the seed is not sown at the appropriate depth into the moist zone and; if the soil is too wet at sowing, creating surface smearing in the furrow. All or one of these may lead to accelerated drying of the seed bed soil and increased soil strength through which the root and shoots have to emerge.

This research aims to determine the soil physical conditions found in the seed bed during the establishment period of chickpea in the HBT of Bangladesh, and how these conditions influence emergence. Research involves growth cabinet studies to determine the critical limits of soil water, soil strength and bulk density as well as field studies to quantity soil physical conditions at sowing after minimum tillage. This paper outlines progress towards defining the seed bed requirements for germination and emergence of chickpea in regards to soil water content.

Methods

Three laboratory experiments were conducted to investigate germination and emergence of chickpea at different water contents. Experiment 1 and 2 were conducted using surface (0 - 10 cm) soil from Merredin, Western Australia with a sandy clay loam (57 % sand, 14 % silt and 28 % clay) and a bulk density of 1.3 g/cm^3 (Russel 2005). Experiment 3 was conducted on surface soil from the HBT in Bangladesh. Previous studies in the region have reported a silty loam soil texture with 43 % sand, 32 % silt and 20 % clay and a bulk density of 1.6 g/cm^3 (Ali 2000). All soils were air-dried and passed though a 4 mm sieve. Soil was wet-up to the treatment water contents and mixed before being left in a sealed container to equilibrate for 48 hours. Seeds of Desi chickpea cv. Genesis 836, were sorted for size and uniformity. In each experiment, gravimetric soil water contents were determined for each treatment at sowing and at harvest. At harvest, seeds were inspected to determine if germination had occurred (radical > 2 mm in length), and if so, root and shoot length were measured and total mass of the seedling taken. If the seed had not germinated it was placed in a petri dish with moist filter paper to determine viability of the seed. Seedlings were classed as emerged when they were first visible on the soil surface. When the seedling emerged the pot was removed and the pot destructively sampled.

Experiment 1 was conducted to determine the soil water content at which chickpea germination is limited. Soil water content treatments were 10, 12, 15, 20, and 25 % by weight. There were three replications of each treatment, which were each destructively sampled over 12 days. Half the soil was placed before eight seeds were evenly sown across a petri dish (1 cm deep, 8 cm diameter) then the other half of the soil was placed on the top of the seeds. The petri dishes were sealed and placed in a growth cabinet at 25 ºC. On days 3, 6, 7, 10, 11 and 12, three replications of each treatment were removed and destructively sampled.

Experiment 2 was conducted to determine how soil water content affected emergence of the chickpea seedlings. Soil water content treatments were 0, 5, 8, 10, 12, 15, 20, and 25 % by weight with eight replications. Soil was placed into square pots 18 cm high and 9 cm wide. Soil was placed into the pots at a bulk density of 1.3 g/cm^3. However, soil water contents of 0, 5, 20 and 25 % all settled to below this value resulting in bulk densities of 1.6, 1.4, 1.6 and 1.8 g/cm^3, respectively. One seed was sown per pot at 3 cm depth. The pot was placed in a sun bag (Sigma-Aldrich) and the sealed bag placed in a growth cabinet at 25 ºC. After sowing, the pots were monitored daily to determine if seed had emerged. Twelve days after sowing all remaining pots were removed and destructively sampled.

Experiment 3 was conducted to determine the soil water content at which chickpea emergence is limited in a soil typical of the HBT in Bangladesh. Soil water content treatments were 8, 10, 12, 15, 18 and 20 % by weight with eight replications. Soil was placed into cylindrical pots 6 cm high and 4 cm diameter. Soil was placed into the pots at a bulk density of 1.3 g/cm^3. One seed was sown per pot at 3 cm depth. The pots were placed in sealed plastic bags and placed in a growth cabinet at 20 ºC. After sowing the pots were monitored daily to determine if seedlings had emerged.

Results

In experiment 1, the actual soil water contents at sowing of the five treatments were 13, 14, 18, 23 and 28 %. At the driest water content (13 %), the rate of emergence at 3 days after sowing (DAS) was 45 %, and rose to 100 % at 11 DAS. With increasing soil water contents the time to germination decreased and at a soil water content at sowing of 18 % germination was 100 % at 3 DAS (Figure 1). As the soil water content at sowing increased to 23 % and 28 %, the number of germinated seeds increased with DAS. Shoot development was also related to soil water content at sowing. At soil water contents ≥ 18 %, germinated seeds showed signs of shoot development at 6 DAS. The number of seeds which had developed a shoot decreased (67 % down to 21 %) when soil water content at sowing increased from 18 to 28 %. With increasing DAS the numbers of seeds with shoot development increased.

Experiments 2 and 3 were conducted to determine the time taken for the chickpea to emerge over a range of soil water contents at sowing and to quantify early differences in root and shoot growth. In the Merredin soil, the soil water contents at sowing covered the range 3 to 27 % (Figure 2). Emergence did not start in any treatment until 4 DAS, and no further emergence occurred after 8 DAS. At 12 DAS, all remaining pots were harvested. At soil water contents of 3, 8, 10 and 27 %, no chickpea seeds emerged over the time of the experiment. In treatments with 12, 14 and 17 % soil water contents at sowing all seedlings emerged. The 17 % soil water treatment had the fastest rate of emergence, with emergence of all seedlings complete by 5 DAS. Chickpea seeds sown into drier soil water contents had delayed emergence, taking 4 to 6 DAS for 14 % soil water and 5 to 8 DAS for 12 % soil water. The 23 % soil water content treatment had 12.5 % of seeds emerge both on 4 and 8 DAS. Of the soil water treatments where no emergence occurred, germination only occurred in 50 % of the seeds sown into a soil water content of 10 %. Of the seeds remaining all the seeds from the 3, 8 and 10 % soil water contents were viable seed, whilst 63 % of the seeds from the 23 and 27 % soil water contents became mouldy.

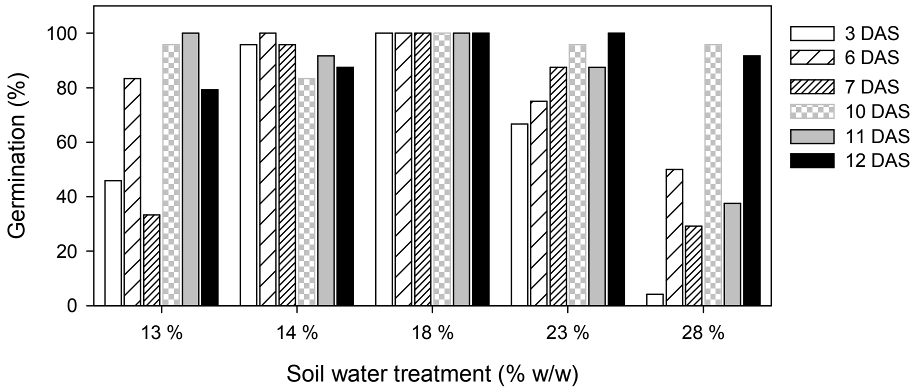

Figure 1. Days to germination of chickpea seeds sown at water contents ranging from 13 to 28 % (w/w) in a Merredin sandy clay loam. Values are means of 3 replicate from experiment 1.

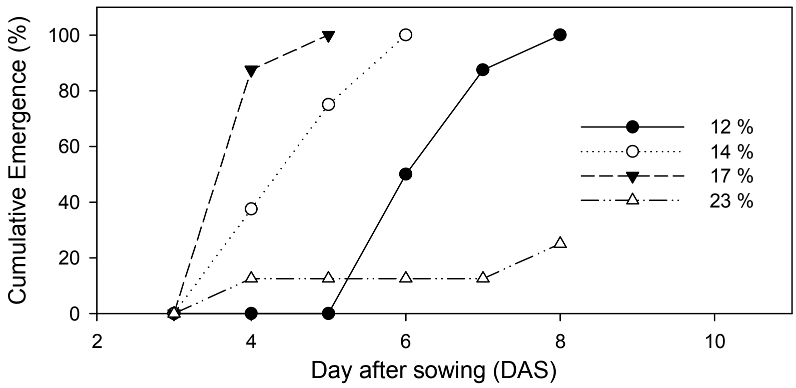

Figure 2. Rate of emergence of chickpea seeds sown into the Merredin sandy clay loam at water contents ranging from 12 to 23 % (w/w) from experiment 2. Note that no seedlings emerged at the soil water contents of 3-10 and 27 %. Eight replicates were sown for each treatment.

In the HBT soil the soil water contents at sowing were from 12 to 23 %. No chickpea plants emerged at the soil water content of 12 %. The soil water content of 19 % had the fastest rate of emergence, although only 75 % of seeds emerged 5 DAS (Figure 3). The rate of emergence of chickpea sown into soil water contents of 16 and 22 % were similar, with 100 % of emergence reached 9 DAS in the 22 % soil water content. The drier and wetter treatments of 14 and 23 %, respectively, had delayed emergence and did not reach 100 % emergence. The chickpea seedlings in the HBT soil pushed up large aggregates of soil in order to emerge, while in the Merredin soil, seedlings were able to break through the soil crust.

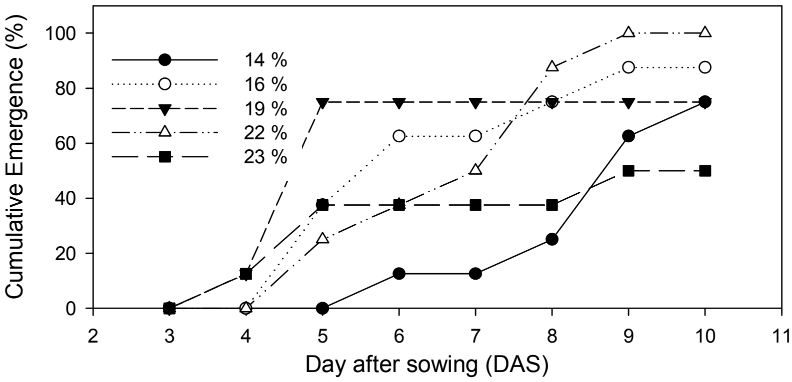

Figure 3. Rate of emergence of chickpea seeds sown into High Barind Tract soil of Bangladesh at water contents ranging from 14 to 23 % (w/w) from experiment 3. Eight replicates were sown for each treatment.

Conclusion

The rate of germination and emergence of chickpea seeds was fastest in soils which had soil water contents at sowing between 17 and 18 %. As the soil dried to 12 %, emergence may be delayed and below 10 %, germination may not occur. In wet conditions above 23 % soil water, germination and emergence are both limited and delayed if they do occur. The two different soil types had different rates of emergence of chickpea depending on the soil water content at sowing. In the Merredin soil type chickpea emergence seemed to be more successful when sown at soil water contents between 12 and 17 %, whereas in the HBT soil, chickpea had slower emergence, but the soil water contents at sowing of 16 to 22 % were the most successful. These differences may be associated with the different soil texture and water holding characteristics of the soil which affect the seeds' requirements for water and aeration for successful germination. These different soils also had different characteristics in regards to aggregates size and distribution that also affected the way the seedling was able to push though the soil to the surface.

References

Ali MY (2000) Influence of phosphorus fertilizer and soil moisture regimes on root system development, growth dynamics and yield of chickpea. PhD Thesis, Bangabandhu Sheikh Mujibur Rahman Agricultural Universtiy.

Baker CJ (2006) Drilling into dry soil. In 'No-tillage seeding in conservation agriculture'. (Eds CJ Baker, KE Saxton, WR Ritchie, WCT Chamen, DC Reicosky, MFS Ribeiro, SE Justice, PR Hobbs) pp. 74-84. (FAO and CAB International: Rome, Italy).

Hadas A (2004) Seedbed preparation -The soil physical environment of germinating seeds. In 'Handbook of seed physiology: applications to agriculture'. (Eds RL Benech-Arnold, RA Sanchez) pp. 3-49. (Food Products Press: Binghamton USA).

Hosseini NM, Siddique KHM, Palta JA, Berger JD (2009) Effect of soil moisture on seedling emergence and early growth of some chickpea (*Cicer arietinum* L.) genotypes. *Journal of Agriculture and Science Technology* **11**, 401-411.

Russel JJ (2005) Major soils of the eastern wheatbelt to characterise soil moisture availability. Department of Agriculture, Government of Western Australia. Resource Management Technical Report 187, Perth.

Saxena NP (1987) Screening for adaption to drought: case studies with chickpea and pigeonpea. In 'Adaption of chickpea and pigeonpea to abiotic stresses, Proceedings of the Consultants' Workshop, 19-21 December 1984'. ICRISAT, India, Patancheru. (Eds NP Saxena, C Johansen) pp. 63-75. (ICRISAT: Patancheru).