EFFECT OF SEED PRIMING AND PLANT SPACING ON THE GROWTH, PRODUCTIVITY AND SOIL HEALTH OF SPRING GROUNDNUT (*Arachis hypogaea* L.)

Thesis

Submitted to the Punjab Agricultural University
in partial fulfillment of the requirements
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MASTER OF SCIENCE
in
AGRONOMY
(Minor Subject: Soil Science)

By

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LUDHIANA – 141 004

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CERTIFICATE – I

This is to certify that the thesis entitled, **"Effect of seed priming and plant spacing on the growth, productivity and soil health of spring groundnut (*Arachis hypogaea* L.)"** submitted for the degree of **M.Sc.** in the subject of **Agronomy** (Minor Subject: **Soil Science**) of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Sanjay B Beesanakoppa (L-2017-A-15-M)** under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigations have been fully acknowledged.

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ABSTRACT

The present investigation entitled "Effect of seed priming and plant spacing on the growth, productivity and soil health of spring groundnut (*Arachis hypogaea* L.)" was carried out at Students' Research Farm, Department of Agronomy, PAU, Ludhiana, for two years during spring season of 2018 and 2019. Three plant spacings comprises 22.5 cm × 20 cm (G_1), 30 cm × 15 cm (G_2) and 45 cm × 10 cm (G_3) allocated in main plot and six seed priming treatments viz. consortium bio-fertilizer (T_1), cow urine (T_2), vermicompost (T_3), vermiwash (T_4), combination of above materials (T_5) and control (T_6) were in sub plot of split-plot design (SPD) with four replications by using spring groundnut variety TG 37A. The results showed that all the growth parameters were significantly influenced by seed priming (except days to 50% flowering), but not by plant spacing. The significantly higher yield attributes were recorded in 22.5 cm × 20 cm (G_1) plant spacing and in control (T_6) among seed priming (except 100 kernel weight). The significantly higher pod yield, haulm yield and biological yield (q ha^{-1}) were recorded in G_1 plant spacing with consortium bio-fertilizer (T_1) seed primed crop. The oil and protein content of spring groundnut kernels, soil enzyme activity (Dehydrogenase & Alkaline phosphatase) and soil available N, P and K (kg ha^{-1}) were influenced non-significantly by both seed priming and plant spacing, but the haulm and kernel N, P and K uptake (kg ha^{-1}) were significantly influenced (except haulm P). The gross & net returns (₹ ha^{-1}) and B: C ratio were significantly higher under G_1 plant spacing with seed priming of consortium bio-fertilizer (T_1) and all the interactional effects regarding above parameters were found to be non-significant (except crop emergence).

Keywords: Seed priming, Plant spacing, Consortium bio-fertilizer, Vermicompost and Vermiwash

Signature of Major Advisor **Signature of the Student**

ਖੋਜ ਦਾ ਸਿਰਲੇਖ	:	ਬਹਾਰ ਰੁੱਤ ਦੀ ਮੂੰਗਫਲੀ (*Arachis hypogaea* L.) ਦੇ ਵਾਧੇ, ਉਤਪਾਦਕਤਾ ਅਤੇ ਮਿੱਟੀ ਦੀ ਸਿਹਤ ਉੱਪਰ ਬੀਜ ਉਪਚਾਰ ਅਤੇ ਬੂਟਿਆਂ ਵਿੱਚ ਫ਼ਾਸਲੇ ਦਾ ਪ੍ਰਭਾਵ
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ਮੌਜੂਦਾ ਅਧਿਐਨ "ਬਹਾਰ ਰੱਤ ਦੀ ਮੂੰਗਫਲੀ (*Arachis hypogaea* L.) ਦੇ ਵਾਧੇ, ਉਤਪਾਦਕਤਾ ਅਤੇ ਮਿੱਟੀ ਦੀ ਸਿਹਤ ਉੱਪਰ ਬੀਜ ਉਪਚਾਰ ਅਤੇ ਬੂਟਿਆਂ ਵਿੱਚ ਫ਼ਾਸਲੇ ਦਾ ਪ੍ਰਭਾਵ" ਸਿਰਲੇਖ ਅਧੀਨ ਪੀ.ਏ.ਯੂ. ਲੁਧਿਆਣਾ ਦੇ ਫ਼ਸਲ ਵਿਗਿਆਨ ਵਿਭਾਗ ਦੇ ਵਿਦਿਆਰਥੀ ਖੋਜ ਫਾਰਮ ਵਿਖੇ ਸਾਲ 2018 ਅਤੇ 2019 ਦੀ ਬਹਾਰ ਰੁੱਤੇ ਕੀਤਾ ਗਿਆ। ਅਧਿਐਨ ਦੌਰਾਨ ਮੂੰਗਫਲੀ ਦੀ ਕਿਸਮ TG 37A ਦੀ ਵਰਤੋਂ ਕਰਕੇ ਮੁੱਖ ਪਲਾਟ ਵਿੱਚ ਤਿੰਨ ਫ਼ਾਸਲੇ 22.5 ਸੈ.ਮੀ. × 20 ਸੈ.ਮੀ. (G_1), 30 ਸੈ.ਮੀ. × 15 ਸੈ.ਮੀ. (G_2), 45 ਸੈ.ਮੀ. × 10 ਸੈ.ਮੀ. (G_3) ਅਤੇ ਉਪ ਪਲਾਟਾਂ ਵਿੱਚ ਛੇ ਬੀਜ ਸੁਧਾਈ ਉਪਚਾਰਾਂ ਭਾਵ ਕਸੰਨਸ਼ੋਰਸ਼ੀਅਮ ਬਾਇਓ-ਫਰਟੀਲਾਈਜ਼ਰ (T_1), ਗਾਂ ਦਾ ਪਿਸ਼ਾਬ (T_2), ਵਰਮੀ ਕੰਪੋਸਟ (T_3), ਵਰਮੀਵਾਸ਼ (T_4), ਉਪਰੋਕਤ ਸਮੱਗਰੀ ਦੀ ਸਾਂਝੀ ਵਰਤੋਂ (T_5) ਅਤੇ ਬਿਨ੍ਹਾਂ ਕੁੱਝ ਪਾਏ (T_6) ਦੀ ਵਰਤੋਂ ਕਰਕੇ ਸਪਲਿੱਟ ਪਲਾਟ ਡਿਜ਼ਾਇਨ ਵਿਧੀ (ਐਸ ਪੀ ਡੀ) ਤਹਿਤ ਤਜ਼ਰਬਾ ਕੀਤਾ ਗਿਆ। ਅਧਿਐਨ ਦੇ ਨਤੀਜਿਆਂ ਤੋਂ ਪਤਾ ਚੱਲਿਆ ਕਿ ਵਿਕਾਸ ਦੇ ਸਾਰੇ ਦੇ ਸਾਰੇ ਮਾਪਦੰਡਾਂ (50% ਫ਼ੁੱਲ ਪੈਣ ਤੋਂ ਇਲਾਵਾ) ਉੱਪਰ ਬੀਜ ਉਪਚਾਰਾਂ ਦਾ ਆਂਕੜਾ ਵਿਗਿਆਨ ਦੇ ਅਧਾਰ ਤੇ ਵਾਧਾ ਹੋਇਆ, ਪਰ ਬੂਟਿਆਂ ਵਿੱਚਲੇ ਫ਼ਾਸਲੇ ਦਾ ਇਹਨਾਂ ਮਾਪਦੰਡਾਂ ਉੱਪਰ ਕੋਈ ਪ੍ਰਭਾਵ ਨਹੀਂ ਪਿਆ। 22.5 ਸੈ.ਮੀ. × 20 ਸੈ.ਮੀ. (G_1) ਫ਼ਾਸਲੇ ਅਤੇ ਬਿਨ੍ਹਾਂ ਕੁੱਝ ਪਾਏ (T_6) ਉਪਚਾਰ ਨਾਲ ਝਾੜ ਦੇ ਸਾਰੇ ਦੇ ਸਾਰੇ ਮਾਪਦੰਡਾਂ (100 ਗਿਰੀਆਂ ਦਾ ਭਾਰ ਤੋਂ ਬਿਨਾਂ) ਦੀਆਂ ਮਿਕਦਾਰਾਂ ਆਂਕੜਾ ਵਿਗਿਆਨ ਦੇ ਅਧਾਰ ਤੇ ਵਧੇਰੇ ਦਰਜ ਕੀਤੀਆਂ ਗਈਆਂ। ਬਾਇਓ-ਫਰਟੀਲਾਈਜ਼ਰ (T_1) ਨਾਲ ਉਪਚਾਰਤ ਬੀਜਾਂ ਅਤੇ G_1 ਫ਼ਾਸਲੇ ਉੱਪਰ ਬੀਜੇ ਗਏ ਬੂਟਿਆਂ ਵਿੱਚ ਫ਼ਲੀਆਂ ਦਾ ਝਾੜ, ਮੂੰਗਫਲੀ ਦੇ ਭੌਂ ਦਾ ਝਾੜ ਅਤੇ ਜੈਵਿਕ ਝਾੜ (ਕੁਇੰਟਲ ਪ੍ਰਤੀ ਹੈਕਟੇਅਰ) ਵਿੱਚ ਆਂਕੜਾ ਵਿਗਿਆਨ ਦੇ ਅਧਾਰ ਤੇ ਵਾਧਾ ਦਰਜ ਕੀਤਾ ਗਿਆ। ਮੂੰਗਫਲੀ ਦੀਆਂ ਗਿਰੀਆਂ ਵਿੱਚ ਤੇਲ ਅਤੇ ਪ੍ਰੋਟੀਨ ਦੀ ਮਾਤਰਾ, ਮਿੱਟੀ ਵਿੱਚ ਇੰਜ਼ਾਈਮ ਗਤੀਵਿਧੀ (ਡੀਹਾਈਡ੍ਰੋਜੀਨੇਜ਼ ਅਤੇ ਐਲਕੇਲਾਈਨ ਫੋਸਫਾਟੇਜ਼) ਅਤੇ ਨਾਈਟ੍ਰੋਜਨ, ਫ਼ਾਸਫ਼ੋਰਸ ਅਤੇ ਪੋਟਾਸ਼ੀਅਮ (ਕਿ.ਗ੍ਰਾ. ਪ੍ਰਤੀ ਹੈਕਟੇਅਰ) ਦੀ ਮਾਤਰਾ ਉੱਪਰ ਬੀਜ ਉਪਚਾਰਾਂ ਅਤੇ ਬੂਟਿਆਂ ਵਿੱਚਲੇ ਫ਼ਾਸਲੇ ਦਾ ਆਂਕੜਾ ਵਿਗਿਆਨ ਦੇ ਅਧਾਰ ਤੇ ਕੋਈ ਪ੍ਰਭਾਵ ਨਹੀਂ ਪਿਆ, ਪਰ ਮੂੰਗਫਲੀ ਦੇ ਭੌਂ ਅਤੇ ਗਿਰਿਆਂ (ਸਿਰਫ ਮੂੰਗਫਲੀ ਦੇ ਭੌਂ ਵਿੱਚ ਫ਼ਾਸਫ਼ੋਰਸ ਤੋਂ ਬਿਨਾਂ) ਵਿੱਚ ਨਾਈਟ੍ਰੋਜਨ, ਫ਼ਾਸਫ਼ੋਰਸ ਅਤੇ ਪੋਟਾਸ਼ੀਅਮ (ਕਿ.ਗ੍ਰਾ. ਪ੍ਰਤੀ ਹੈਕਟੇਅਰ) ਦੇ ਗ੍ਰਹਿਣ ਦੀ ਮਿਕਦਾਰ ਉੱਪਰ ਆਂਕੜਾ ਵਿਗਿਆਨ ਦੇ ਅਧਾਰ ਤੇ ਪ੍ਰਭਾਵ ਪਿਆ। ਬਾਇਓ-ਫਰਟੀਲਾਈਜ਼ਰ (T_1) ਨਾਲ ਉਪਚਾਰਤ ਬੀਜਾਂ ਅਤੇ G_1 ਫ਼ਾਸਲੇ ਉੱਪਰ ਬੀਜੀ ਫ਼ਸਲ ਤੋਂ ਕੁੱਲ ਮੁਨਾਫ਼ਾ, ਸ਼ੁੱਧ ਮੁਨਾਫ਼ਾ ਅਤੇ ਲਾਭ: ਲਾਗਤ ਅਨੁਪਾਤ ਵਧੇਰੇ ਪ੍ਰਾਪਤ ਹੋਇਆ ਪਰ ਫ਼ਸਲ ਵਿੱਚ ਫ਼ੁੱਲ ਆਉਣ ਤੋਂ ਇਲਾਵਾ ਉਪਰੋਕਤ ਦਰਸਾਏ ਗਏ ਸਾਰੇ ਦੇ ਸਾਰੇ ਮਾਪਦੰਡ ਆਂਕੜਾ ਵਿਗਿਆਨ ਦੇ ਅਧਾਰ ਤੇ ਬਰਾਬਰ ਸਨ।

ਮੁੱਖ ਸ਼ਬਦ: ਬੀਜ ਉਪਚਾਰ, ਬੂਟਿਆਂ ਵਿੱਚਲਾ ਫ਼ਾਸਲਾ, ਕੰਨਸ਼ੋਰਸ਼ੀਅਮ, ਵਰਮੀ ਕੰਪੋਸਟ ਅਤੇ ਵਰਮੀ ਵਾਸ਼

ਮੁੱਖ ਸਲਾਹਕਾਰ ਦੇ ਹਸਤਾਖਰ | **ਵਿਦਿਆਰਥੀ ਦੇ ਹਸਤਾਖਰ**

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CHAPTER I

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an important oilseed and cash crop of India and it contributes about one third of the major oilseeds produced in the country. Groundnut is the sixth most important oilseed crop and third most important vegetable protein in the world. The oilseed sector is the major division which governs the agricultural economy of our country and it contributes maximum imports of the country in agricultural sector as vegetable oil. Among oilseeds, groundnut is major exporting agricultural commodity. Groundnut is known by many local names such as earthnut, peanut, monkey nut and goober pea and it also known as king of oil seeds. Botanical name of groundnut (*Arachis hypogaea* L.) assigned by botanist Linnaus due to its leguminous nature (*Arachis*) and fruiting character below the earth surface (*Hypogea*). Groundnut belongs to family *Leguminosae* (Fabaceae) and sub-family *Papilionodeae*. Groundnut is phenotypically well defined and clearly described from its closest relatives by the presence of geocarpic peg. Being legume crop, groundnut is mainly classified as grain legume and oilseed crop due to its high oil content. The different agro-ecological regions of India are suitable for cultivation of all nine annual (edible and non-edible) oilseed crops, among these groundnut ranks second which is next to soybean. As per nutrition concern the kernels of groundnut contain high quality oil (43-55%), protein (25-28%) and lower range of carbohydrates (13-16%) of total weight along with vitamins (E, K and B complex). Groundnut oil comprises 40-50% (MUFA- oleic acid) and 25-35% (PUFA-linoleic acid).

Groundnut is cultivated in both tropical and sub-tropical countries, lying between 45^0 N and 35^0 S varied with different soil and climatic conditions. It is sixth most important oilseed crop of the world cultivated on 27.74 million hectare land with production of 47.10 million tonnes, on an average productivity of 1.69 tonnes per hectare during 2017 (Anonymous 2017a). China is the major producer of groundnut followed by India, which accounting for over 41% and over 18% of the world production respectively. India produced 9.25 million tonnes of groundnut with an average yield of 1.89 tonnes per hectare from 4.89 million hectare area during 2017-18 (Anonymous 2017b).

In Punjab, groundnut was grown on an area about 1.2 thousand hectares with production of 2.34 thousand tonnes and productivity of 1.95 tonnes per hectare during 2017-18 (Anonymous 2017c). In India, groundnut is available throughout the year due to its two-crop cycles, mainly grown in *kharif* season (June to October) under rainfed conditions using low inputs with high pressure of insect-pests, diseases and weeds with low productivity. It also grown as spring or summer crop (March to June) with assured irrigation, reduced insect-pests and diseases along with higher productivity.

Yield of any crop is a complex phenomenon, as it is a function of genetic factor as influenced by climate and management practices. Even though the crop with superior genetic characters grown under congenial environmental conditions will not give better yields due to poor management practices, such as low or high soil moisture, spacing, improper germination, varied plant population and plant nutrition etc. Quick and uniform field emergence is a crucial requirement to produce higher crop yield, better quality and monitory returns from crops (Parera and Cantliffe 1994). Higher and uniform germination is must for attaining optimum seedling establishment and higher productivity, but numerous ecological constrictions in crop production (Wahid *et al* 2008). One practical method to enhance crop production is seed priming (Basra *et al* 2004, Farooq *et al* 2006 and Lee and Kim 2000) and other one is optimum plant population.

Heydecker *et al* (1973) defined seed priming a process of limited hydration of seeds to a level, which permits germination, but prevents actual radicle emergence. Seed priming is an important operation to achieve high percentage of germination, early and uniform emergence of crop and enhancement of ability of plants to withstand against biotic and abiotic stress conditions. Seed priming includes halo priming, hydro priming and osmo-priming etc. (Chiu *et al* 2002, Kao *et al* 2005 and Windauer *et al* 2007). It increases the plant vigour, growth and yield potential of crop and also saves money and time of farmers due to reduced fertilizer requirement and reseeding.

Numerous experts described that seed priming enhances the germination proportion and improves seedling establishment and growth in rapeseed (Basra *et al* 2003 and Mohammadi 2009). It had positive effect on germination characteristics of other crops, such as sweet corn (Chiu *et al* 2002), maize (Murungu *et al* 2003) and cotton (Toselli and Casenave 2003).

Seed priming has been usually suggested to condense the time between sowing and crop emergence to achieve synchronized development (Parera and Cantliffe 1994). It has significant effect in enhancement of yield of various crops to the tune of 40, 20.6, 37, 50, 56, 22 and 37% in barley, chick pea, maize, pearl millet, sorghum, upland rice and wheat, respectively (Harris *et al* 2005).

Chattopadhyay (2015) reported that micronutrients and growth promoting substance present in vermiwash shows positive effect on germination of green gram (*Vigna radiate*) seeds and vigor of the seedlings. The same results were recorded in wheat crop when primed with cow urine (Shivamurty 2005). Higher soil electrical conductivity (EC) will inhibit the germination in almost all crops due high salt concentrations, while seed primed with $CaCl_2$

(1%) will reduce the soil EC due to beneficial effect of $CaCl_2$ in strengthening the cell membrane integrity and cell wall permeability in groundnut (Tagad *et al* 2015).

Plant spacing is another key factor which regulates the growth and yield of field crops. To accommodate definite number of plants per unit area (plant density) and to get higher yield, optimum plant spacing is required. The proper farming procedure and plant density are desired to fully utilize the groundnut's genomic potential for higher yield. Plant spacing not only governs competition for light and nutrients, but also controls the circulation of photosynthates among the organs and eventually increases pod yield (Giayetto *et al* 2003, Zheng *et al* 2007, Rasekh *et al* 2009, Song *et al* 2011 and Chen *et al* 2013).

Inappropriate spacing and plant population may distress the regular physiological activities of the crop. In densely populated crop, competition among the plants are more. Again, broader spacing gives lower yield due to inefficient utilization of space. There are two general concepts to describe the relationship between plant population and seed yield. i.e. (i) Irrespective of inter and intra-row plant spacing, plant geometry must be such that the crop grows a canopy which is able to capture more than 95% of the incident solar energy throughout early reproductive phase and increase the seed yield (Johnson *et al* 1982). (ii) Nearly intermediate plant arrangement reduces inter-plant competition and resulted in higher seed yield (Wells 1993).

Awal and Lija (2015) reported that line to line spacing have substantial effect on growth and yield enhancing attributes like number of shoots, total leaf area, dry weight of the plant, pods per plant and test weight. They further reported that close spacing increases plant height but reduces number shoots per plant and wider plant spacing promotes the final plant yield and pods per plant. The benefit of wider distance between plants is permitting a larger area for plants to uptake water, nutrients and absorb sunlight which are often yield restrictive aspects in crops like corn (Farnham 2001).

After increasing the plant density, tapering row spacing is classically a common substitute to decrease intra-row competition or high density of plants (Butzen and Paszkiewicz 2008). So, keeping this in view, the study on "Effect of seed priming and plant spacing on the growth, productivity and soil health of spring groundnut (*Arachis hypogaea* L.)" was planned with following objectives:

- To evaluate the suitable seed priming and plant spacing which enhance the growth, yield, quality and productivity of spring groundnut.
- To study the effect of different sources of seed priming and plant spacing on soil physical, chemical, biological properties and their interactional effect on higher productivity and economic feasibility of spring groundnut.

CHAPTER II

REVIEW OF LITERATURE

Seed priming is a technique in which seeds are pre-soaked before sowing or planting. It recently known as seed treatment which results in quick and uniform emergence of crop plants even under harsh environmental conditions. Seed priming enhances seed germination and results in increased plant vigour, growth and yield potential of crop. It augments germination by maintaining temperature and seed moisture content. Hence it saves money and time of farmers due to reduced fertilizer requirement, reseeding and better plant growth. The seed priming of groundnut with *Rhizobium*, Phosphate Solubilizing Bacteria (PSB), *Arbuscular Mycorrhiza* (AM) and other seed priming materiel increases the protein and oil concentration in kernels, oil productivity and profit along with higher N and P concentration and their absorption over nontreated seeds. The *rhizobium* treated plants shows higher N, P and K absorption compared to plants without any treatment (Sharma *et al* 2014). Chattopadhyay (2015) reported that micronutrients and growth promoting substance shows positive effect on germination of green gram (*Vigna radiata*) seeds and vigor of seedlings when treated with vermiwash. The similar results related to plant growth such as plant height, dry matter accumulation in leaf, stem and ear head were reported by Shivamurty (2005) in wheat crop treated with cow urine. Singh *et al* (2010) observed that solicitation of recommended dose of fertilizer (RDF) enhanced the seed yield of lentil over control. They further reported that applied vermicompost have higher tendency to enhance the grain yield of lentil over control.

Plant spacing is another key factor which regulates the growth and yield of groundnut. Suitable plant spacing is needed to maintain optimal population to take intercultural practices along with higher yield. Whereas close spacing of groundnut maintain the complete crop cover over the soil which prevents weed seed germination and cuts the number of weeding operations (Lee *et al* 1994). Quick canopy closure by dense planted crop has been shown the smother effect on weeds, hence declines weed/crop competition, specifically for soil nutrients and water (Coolman and Hoyt 1993 and Thellen 2006). Narrow spacing also shown significant reduction in incidence and spread of tomato spotted wilt virus (TSWV) in groundnut crop (Branch *et al* 2004) due to dilution of vectors, results in lower individual plant infection (Brown *et al* 2005 and Jadhav 2006). The higher crop yield in close spaced crop mainly attributed to higher plant population that efficiently utilize water, nutrients (Mickelson and Renner 1997 and Ahmad *et al* 2007) and most prominently light (Wells *et al* 1993 and Dalley *et al* 2004) along with the application of inorganic fertilizers (Schilling and Gibbons 2002). Ultimately close spaced groundnut gives higher pod yield (Jaaffar and Gardner 1988) but yield per plant is restricted due to higher plant population.

The wide plant spacing increases the per plant pod yield (Onat *et al* 2017) but total yield is reduced due to low plant density under wider spacing. Awal and Lija (2015) also reported the substantial effect of plant spacing on growth and yield enhancing attributes. They further reported that close spacing showed the increased plant height but lower number of shoots per plant and wide plant spacing promotes per plant pod yield.

The both dense and distant plant population suffers from neighboring plant competition and improper utilization of land in response to variation in light and other environmental resources available to each plant respectively (Ali *et al* 2003) and finally the grain yield per plant is decreased (Luque *et al* 2006), resulting in reduction of total yield.

The seed priming and varied plant spacings are old practices in the cultivation of groundnut. But the combined study of seed priming along with different plant spacing is new one. Inspection of literature revels extensive agronomic studies available on seed priming of groundnut with various priming materials and response of groundnut under different crop geometry separately, but literature on combined work is scattered and scanty. Therefore, seed priming with different plant spacing in groundnut has been reviewed to draw valid conclusions. The available literature is reviewed as under:

2.1 Effect of seed priming and plant spacing on growth, yield and productivity

2.2 Effect of seed priming and plant spacing on seed quality

2.3 Effect of seed priming and plant spacing on soil properties

2.4 Effect of seed priming and plant spacing on economic feasibility

2.1 Effect of seed priming and plant spacing on growth, yield and productivity

Singh *et al* (2011) carried out a field experiment to conclude the results on groundnut yield by supplying nutrients through biofertilizers, organic and inorganic sources. The treatments comprised of four biofertilizers viz. *Rhizobium,* Phosphate Solubilizing Microorganisms (PSM), *Rhizobium* with PSM and control, along with seven types of nutrient mixtures such as control, lime at 500 kg ha^{-1}, FYM at 10 t ha^{-1}, Lime + 50% NPK, FYM + 50% NPK, Lime +FYM + 50% NPK and suggested dosage of NPK (20:60:40 kg ha^{-1}). Plants treated with *Rhizobium* + PSM considerably enhanced peanut pod yield (25.27 q ha^{-1}) which was 23.82% more than that of control treatment. Whereas sole treatment with *Rhizobium* recorded higher haulm yield (41.47 q ha^{-1}) and also recorded 18.6 % and 10.12% increased pod yield over control and the yield improvement alone by biofertilizers was about 10-25% higher than other treatments. In other treatment highest pod production was obtained with Lime + FYM + 50% NPK about 6.8% and 13.14% greater than FYM + 50% NPK and 100% NPK alone respectively. The highest pod yield (30.32 q ha^{-1}) was obtained by Lime + FYM +

50% NPK in combination with *Rhizobium* + PSM, which was 2.5%, 11.92% and 21.71% greater than same treatment separately treated with *Rhizobium*, PSM and control respectively.

Chada *et al* (2012) studied the efficiency of vedic krishi inputs as treatments such as panchagavya, vermiwash, compost tea, markakhad, jiwamrit and beejamrit in nutrient and disease management. They reported that application of vermiwash increases 65%, 10%, 26% and 27% more yield in knol-khol (153.3 q ha^{-1}), frenchbean (14.5 q ha^{-1} grain yield), onion (18.4 q ha^{-1}) and paddy (18.4 q ha^{-1}) respectively over control.

Wolie *et al* (2017) studied the response of seed treatment on germination, yield and fusarium head scab of common wheat. The treatments comprises of control, water soaking, cow urine treatment, Dynamic 200FS, water + Dynamic 200FS, cow urine + Dynamic 200FS, Dynamic 200FS + Disco™ AG Red L-431, water + Dynamic 200FS + Disco™ AG Red L-431, cow urine + Dynamic 200FS + Disco™ AG Red L-431, Dynamic 200 FS + Disco™ AG Red L-431 + Genius coat™, water + Dynamic 200 FS + Disco™ AG Red L-431 + Genius coat™ and cow urine primed + Dynamic 200 FS + Disco™ AG Red L-431 + Genius coat™. Among these water-soaked seeds showed faster germination (6.3 days), heading (67.5 days) and early maturity (112.8 days) over other treatments followed by cow urine treated seeds 7.17, 68.33 and 114.0 days respectively.

Shivamurty (2005) studied the response of wheat cultivars to seed priming. The seed priming treatments consisting of control, water soaking, cow urine priming and $CaCl_2$ priming. Seed priming with cow urine resulted in higher leaf dry weight (41.24 g m^{-1} row length) compared to control and water-soaked seeds. Enhanced stem dry matter 49.45 and 48.47 g m^{-1} row length of crop were recorded in cow urine and $CaCl_2$ primed plants respectively.

Awal and Lija (2015) reported the effect of inter row spacing on growth and yield of groundnut. This experiment consists five different row spacings such as 15, 20, 25, 30 and 35 cm with fixed intra-row spacing of 15 cm in RBD design. They reported that inter and intra-row arrangement of plants had substantial effect on growth and yield attributing characters like plant height, total shoot $plant^{-1}$, total leaf area, dry matter addition, pods $plant^{-1}$, economic yield, biological yield and B:C ratio. They further reported that plant height was increased in close inter row spacing, but the close inter row spacing from 35 cm to 15 cm shows negative effect on total shoots $plant^{-1}$ over wide spaced planting (35 cm) and the wide spacing accumulates higher dry material (23 g) $plant^{-1}$. However higher biomass (530 g m^{-2}), greater seed (2.01 t ha^{-1}) and pod yield (2.82 t ha^{-1}) were observed under 20 cm inter row spacing and lower yield were recorded in further increased row spacing.

Onat *et al* (2017) reported similar results as given by Awal and Lija (2015) in their experiment, that 'the response of inter and intra-row spacing on yield and its parameters of

groundnut'. The treatment comprises of two inter row spacing of 70 and 75 cm and five intra-row spacings such as 5, 10, 15, 20 and 25 cm and cultivating groundnut variety Halisbey for two years. They recorded pod weight of 97.57 g and 94.83 g plant^{-1}, 96.4 and 93.5 pods plant^{-1} respectively in 75 x 25 cm plant spacing with in their respective years. The highest total no. of pods and pod weight plant^{-1} were recorded under reduced plant population. But greater mean pod yield of 0.751 t ha^{-1} (mean of two years) was reported from 75 x 10 cm and least (0.517 t ha^{-1}) from 75 x 25 cm plant spacing.

Kumar and Sachan (2015) conducted an experiment to evaluate response of pre-sowing seed treatments on yield and quality of groundnut using cultivar VLG-1. Seven various pre-sowing seed invigoration was taken namely hydration for 16 h followed by air drying at room temperature (T_1), cold hydration for 72 h at 10^0 C and surface drying (T_2) , hydration with 50 ppm GA_3 for 16 h followed by surface drying at room temperature (T_3), osmo-conditioning (PGA) solution (-10 bars) for 15^0 C for seven days (T_4), dressing with Thiram (75%DS) @ 0.25 % after hydration for 16 h (T_5), hydration with 2% KH_2PO_4 for 16 h followed by drying at room temperature (T_6) and finally dry seeds without any treatment using as a control (T_0). They registered consistently and significantly higher pod yield (12.94 q ha^{-1}) in T_5 than untreated seeds (11.15 q ha^{-1}). The maximum pod yield produced by significantly higher field emergence (87.83%), higher plant stand and better crop establishment. They also reported that osmo-conditioning had highly detrimental effects on germination, field emergence (29%) and all the other parameters of the crop.

Tagad *et al* (2015) showed that, the seed priming significantly increases the yield contributing characters and seed yield of groundnut compared to un-primed seeds. The highest seed yield was noticed in $CaCl_2$ (1%) primed seeds followed by KCl (1%). The $CaCl_2$ (1%) seed primed treatment recorded the maximum plant height (38.9 cm), more no. pods (39 plant^{-1}), higher 100 seed weight (36.8 g), and seed yield per hectare (36.6 q) followed by KCl (1%). They also reported lower EC (dS m^{-1}) of seed leachates in $CaCl_2$ (1%) treated seeds over un-primed seeds and other treatments such as hydration, KH_2PO_4 priming, seed priming with 1% boron, 25ppm GA_3 and seed soaking in 0.5 % $MnSO_4$ for 6 h followed by shade drying in all the treatments. Bose and Saxena (1999) also reported, the results of seed priming on seedling behaviour of partly aged groundnut seeds to enhance the seedling performance of such seeds through PGR pre-soaking treatments using groundnut cultivar ICGS 67. They reported that treatment of gibberellic acid (GA_3) and kinetin (Kn) alone or in combination was the best as evident from the seedling performance in terms of germinability of 90, 95 and 85%, respectively and also recorded high dry matter production and its mobilization in plants.

Badawi *et al* (2011) studied the capability of various rhizo-microbial cultures (*Serratia marcescens* and *Trichoderma harzianum*) along with *Bradyrhizobium spp*. A field

trials were conducted by co-inoculating seeds with *Bradyrhizobium* either individually or together with *S.marcescens* and/or *T.harzianum* to study the effect on nodule formation and growth characters, yield parameters and and yield of groundnut. However, the major action on groundnut nodulation, nitrogen fixation and vegetative characters were noticeable in inoculation of *Bradyrhizobium* with *S.marcescens*. The higher pod yield (48.6 q ha^{-1}) and stover yield (54.5 q ha^{-1}) were recorded in same treatment which is significantly more over the control (30.4 q and 40 q ha^{-1} respectively) and other treatments.

Sajid *et al* (2011) studied the influence of *rhizobium* inoculation on growth and yield of groundnut. The results show that *rhizobium* application improve the growth and yield attributes of groundnut cultivars significantly. However, the highest plant height (88.43 cm), number of branches (19.9), leaves (173.3), pods (79.8), nodules (156.3) and yield (252.7 g) $plant^{-1}$ and pod yield (18.6 q ha^{-1}) were observed in *rhizobium* inoculated seeds, which is superior over the control (13.92 q ha^{-1}) and in turns all the other parameters.

Tahir e*t al* (2017) also considered seed priming is an important component that results in early establishment of crop seedling. Thus, iron (Fe) and zinc (Zn) effect on growth and yield components of groundnut (cv. BARI-2011) was evaluated by using different doses of Fe (0.1% and 0.3%) and Zn (0.5% and 1.0%) seed priming treatments in RCBD design with two factors, replicated it thrice. Data revealed that plant height and number of shoots were the maximum at 0.3% Fe in combination with 1.0% Zn. Similarly, numerical values for all measured yield components i.e. number of pods $plant^{-1}$ (45.1), kernel weight (18.0 q ha^{-1}), 100 kernel weight (64 g), pod yield (26.0 q ha^{-1}), biological yield (78.5 q ha^{-1}) with harvest index (33%) and shelling percentage (69.1%) were significantly higher at 0.3% Fe in combination with 1.0% Zn as over control. The control plot resulted in the least numericals for all the parameters studied.

Gadade *et al* (2018) conducted an agronomic field investigation to conclude the effect of different spacings on growth and yield of broad bed furrow (BBF) raised summer groundnut under drip irrigation. The experiment comprising of five treatments of spacing viz. 20cm × 20cm, 22.5cm × 10cm, 30cm × 7.5cm, 30cm ×10cm and 30cm × 15 cm. All the treatments were replicated four times in RBD design. The important findings emerged from this investigation were the summer groundnut sown at the of spacing 22.5cm × 10 cm recorded significantly higher plant height (27.1 cm) which was comparable with spacing 30cm ×10 cm and 30cm × 7.5 cm. Significantly higher dry matter accumulation (24.5 g) of summer groundnut was observed in spacing 30 cm × 15 cm and it was comparable with spacing 22.5cm × 10cm and 30cm ×10cm. Yield contributing parameters viz. number of pods (30) and pod weight per plant (19.75 g) and shelling percentage (%) were significantly higher in spacing 30cm × 15cm and was comparable with spacing 20 cm × 20 cm and 30cm ×10 cm.

Maximum dry pod yield (46.22 q ha^{-1}) was produced in spacing 30cm × 7.5cm and was comparable with spacing 22.5cm × 10cm and 30cm × 10cm.

Changxing *et al* (2017) conducted an experiment to determine the effects of planting density on pod development and yield of groundnut under the mode of single seeded precision sowing using Luhua 11 groundnut variety. They showed the precision sowing plant density of 195000 and 225000 per hectare was optimal to produce high DMA and more no. of pods for the improvement of pod yield i.e. 55.5 q and 54.3 q ha^{-1} respectively. The increased plant density (255,000 plants per hectare), recorded pod yield of 51.0 q per hectare. The yield under single seeded precision sowing was higher over double seeded (49.95 q ha^{-1}) precision sowing method.

Gabisa *et al* (2017) observed the effect of plant density on yield and yield components of groundnut crop. The experiment was performed in RCBD design with five plant spacings (70 cm × 10cm, 60 cm × 10cm, 50 cm × 10cm, 40 cm × 10cm and 30 cm × 10cm) and replicated thrice. They recorded significant effect of plant spacing on total pods and matured pods per plant, dry pod yield and seed yield. The highest above ground dry biomass (6050 kg ha^{-1}) recorded in closer plant spacing of 30 cm × 10cm, but the highest pods per plant (77.3) reported under 70 cm × 10cm spacing although the highest pod yield (3831 kg ha^{-1}) and seed yield (2790 kg ha^{-1}) were recorded in 40 cm × 10 cm plant geometry . Yenagi *et al* (2017) also confirmed 30 cm x 10 cm plant spacing gave the highest pod yield (3845 kg ha^{-1}) over 30 cm x 20 cm spacing (2927 kg ha^{-1}).

Abuzar *et al* (2011) studied the effect of different plant density on maize yield with six plant densities i.e. 40000 (T_1), 60000 (T_2), 80000 (T_3), 100000 (T_4), 120,000 (T_5) and 140,000 (T_6) plants ha^{-1}. The respective plant densities were accommodated by intra-row spacing of 33.3 cm in T_1, 22.7 cm in T_2, 18.6 cm in T_3, 13.5 cm in T_4, 11 cm in T_5 and 9.6 cm in T_6 with common inter row spacing of 75 cm in all treatments. They further reported that the population density 40000 ha^{-1} showed the highest number of grains per row (32.33) and per ear (447.3). However, the maximum number of ears per plant (1.33) were noticed under 60000 plant density ha^{-1}, which also produced biomass yield of 168.9 q ha^{-1} and grain yield of 26.1 q ha^{-1}.

Onat *et al* (2017) examined the effect of different plant spacings i.e. two inter-row distances (70 and 75 cm) and five intra-row spacings (5, 10, 15, 20 and 25 cm), on number of pods, pod weight $plant^{-1}$ and pod yield. The number pods $plant^{-1}$ ranged between 64.0 and 67.0 in the row distance from 70 cm and 75 cm respectively. The highest pods $plant^{-1}$ (95.0) were obtained from 75 cm row spacing and least in 70 cm row spacing (26.7). Whereas the highest number of pods were obtained with crop sown under 25 cm inter row spacing. The maximum pods $plant^{-1}$ were recorded under 75 x 25 cm (53000 plants ha^{-1}) and 70 x 25 cm

(57000 plants ha^{-1}). The variability of row distances and plant spacings have significant effect on pod weight $plant^{-1}$ i.e. 65.3 g and 67.4 g $plant^{-1}$ in the row distance 70 cm and 75 cm respectively. Similar results were obtained by increasing plant spacing from 5 cm to 25 cm and the increased pod weight was 24.5 g and 96.2 g $plant^{-1}$ respectively. The maximum pod weight $plant^{-1}$ was recorded at 75 cm x 25 cm and 70 cm x 25 cm and least in 70 cm x 5 cm and 75cm x 5 cm plant spacings. The pod yield was significantly more under 70 cm row distance (64.88 q ha^{-1}), whereas least yield recorded at 75 cm plant spacing (62.58 q ha^{-1}). The same results were obtained from the intra-row spacing such as 10 cm plant spacing produced highest pod yield (74.84 q ha^{-1}) and lowest under 5 cm spacing (67.42 q ha^{-1}) and least under 25 cm spacing (52.88 q ha^{-1})

2.2 Effect of seed priming and plant spacing on seed quality

Rajpar *et al* (2006) reported the seed priming effect on grain yield and P and K content in wheat grains. The experiment comprises of four treatments namely control, hydropriming, priming with 0.2% gypsum and priming with 0.4% gypsum. The result showed that highest grain yield was noticed in hydro-primed seeds (28.96 q ha^{-1}) followed by 0.4% gypsum (28.35 q ha^{-1}) and least yield were recorded in control (23.24 q ha^{-1}). The same results were noticed in case P and K content of wheat grains i.e. highest P and K concentration in wheat grains were recorded in hydro-primed seeds (0.335% and 0.6%) followed by 0.4% gypsum primed seeds (0.330% and 0.59%) and least in control (0.322% and 0.58) respectively.

Hafeez *et al* (2011) conducted an experiment to evaluate the effect on-farm seed priming effect in direct seeded rice by using different priming methods such as on-farm priming, hydropriming, hardening and osmo-hardening with $CaCl_2$ and KCl and a control. Among all methods, osmo-hardening with $CaCl_2$ showed improved crop stand, crop establishment, agronomic traits, yield and quality of paddy over other priming practices and control. Osmo-hardening with $CaCl_2$ was recorded lowest chalky kernels (12.67%) and improved kernel length (11.25 mm) along with improved phosphorus (0.467%), calcium (0.27%) and potassium (0.477%) contents in grain followed by KCl primed treatment.

Sharma *et al* (2014) found the superior performance of *Rhizobium* compared to control. They study the effect of different fertility levels and biofertilizers on nutrient content, absorption and on quality of groundnut. The treatments comprise four fertility levels (0, 50, 75 and 100%) and four bio-fertilizer seed treatments (*rhizobium*, PSB, AM and control) and RDF of 20 kg N and 60 kg P_2O_5 ha^{-1}. The results showed that higher dose of recommended fertilizer significantly improves the P concentration in kernel. Significantly higher protein content, oil content and oil yield of groundnut were recorded in *rhizobium* treated crop which was 11.3%, 13.7% and 41.8% higher than control respectively. PSB and AM also statistically

higher than control. The higher N(175.7 kg ha^{-1}) and K (64.5 kg ha^{-1}) uptake by the plant was recorded in *rhizobium* treated plants followed by PSB and AM and lower nutrient absorption were recorded in control.

Mubshar *et al* (2006) conducted a field study to evaluate the influence of seed priming techniques on the seedling establishment, yield and quality of hybrid sunflower. Seeds were hydro primed, hardened and matri-primed for 24 h respectively and matri-primed for 48 h, osmo-primed with 0.5% KNO_3 and osmo-primed with 0.1% NaCl for 12 h. The maximum number of achenes $head^{-1}$ (900.3), 1000 achene weight (55.23 g), biological yield (7.25 q ha^{-1}) and achene yield (2.26 q ha^{-1}) and highest achene proteins (30.38%) were recorded in hardened seeds, which was similar to that of osmo-priming with NaCl (30.3%). However, minimum number of achenes $head^{-1}$ (757.7), biological yield (6.05 q ha^{-1}) and achene yield (1.6 q ha^{-1}) was recorded in hardened seeds but lowest achene protein was recorded in matri-primed seeds for 24 h followed by 48 h.

Abubaker (2008) found the effect of plant density on yield and quality attributes of Bush Beans with six plant densities as treatments. Those are 10 cm, 20 cm, 30 cm, 40 cm, 50 cm and 60 cm as intra-plant spacing and a fixed inter plant distance of 30 cm. The narrow planting (30 × 10 cm) was yielded lowest among all treatments. The highest bean yield was recorded in 30 cm × 20 cm spacings (12.55 q ha^{-1}) and 30 cm × 30 cm geometry (12.09 q ha^{-1}) respectively. The 30 cm × 60 cm spacing gives least yield compared to all treatments. As per quality concern reduced plant density showed increase in N, P, K and protein content of bean seeds i.e. 3.56%, 0.37%, 3.61% and 22.5% respectively, where least numericals were recorded in higher plant densities.

Onat *et al* (2017) examined the performance of various plant spacings on protein and oil content of groundnut i.e. two row distances (70 and 75 cm) and five different plant spaces (5, 10, 15, 20 and 25 cm), totally consisting of 10 plant geometries. The oil and protein content of crop grown in 70 cm and 75 cm row distance does not affected, whereas the intra-row spacing influenced it significantly. The highest protein content (24 %) was reported in 5 cm plant spacing and the lowest (22.7%) under 25 cm, where highest (47.55%) and lowest (45.5%) oil content were observed under 25 cm and 5 cm intra-row spacing respectively.

2.3 Effect of seed priming and plant spacing on soil properties

Aiguo *et al* (2019) found the effect of plant density on soil characteristics such as bulk density, pH and soil nutrients. The experiment comprised of five different plant densities such as 1667 (2m × 3m), 3333 (2m × 1.5m), 5000 (2m × 1m), 6667 (1m × 1.5m) and 10000 (1m × 1 m) plants ha^{-1}, by planting two-year old seedlings of Chinese fir tree for 30 years. The densities were represented as A, B, C, D and E respectively. The soil pH in high-density stands is higher than in the low-density stands, and the five densities demonstrated a

consistent change in soil pH in different soil layers. For the A planting density, a significant difference was found in the soil bulk density between the 0–60 cm soil layers and the soil layers below 60 cm i.e. 3.61 g and 3.82 g kg^{-1} of soil respectively. The planting density had an obvious effect on the organic matter content soil at different layers. In surface soil (0–30 cm) of both A and B densities higher organic matter (32.33 g and 32.8 g kg^{-1} soil) content was found, which is higher than other densities. The 0–10 cm soil layer in the A density had more organic matter content (43 g $kg^{-1}$of soil) than in the other planting densities and the soil in the D density had the lowest organic matter content (37 g kg^{-1} soil). As per nutrients concern the total N and available N in soil exists in an organic state. Both the soil total N and the available N consistently changed with Chinese fir tree planting density. With the increase in density, the total and available N contents in all soil layers decreased to a little as a whole. The total N content in the A density (0.8 g kg^{-1} soil) was generally higher than that in the other density. Total P and Available P shows that no significant difference among the different plant stands existed in the total P content in all soil layers, but their total P content was greater in the C, D, and E stands. The total K content in all soil layers tends to decrease first and then increase with the increase in density. The total K content in D and E stands was higher than in the other density stands and the content in the B density stand was the lowest (1.0 g kg^{-1} soil) and highest in the E stand (1.7 g kg^{-1} soil).

Oliver and Rattan (1987) conducted an experiment to study the effect of plant density on soil structure, soil moisture and yield of cassava. The experiment comprised of four plant spacings such as 0.5 m, 0.75 m, 1 m and 1.25m with a common row spacing of 1 m to give a population of 20000, 13300, 10000 and 8000 plants ha^{-1} respectively. The experimental plot having dimension of 4m x 4m was kept as bare plot. The results showed that the plant density showed a non- significant effect on soil bulk density up to 40 cm depth, but higher bulk density of 1.53 cm^3 was observed under bare plots and it was 17% higher than cultivated soil. The moisture holding capacity for the 0-10, 10-20 and 20-40 cm soil depths were analysed for four cassava population and the uncultivated plots. Among cassava planted situation a significant difference was observed with respect to moisture retention capacity of the soil for some suctions between cultivated and uncultivated bare plots. The lowest moisture retention at 0-10 cm depth was noticed in uncultivated bare plots at suction range of pF < 2.4. The effect of plant population on moisture retention capacities for the higher suction range (pF> 3.2) was more pronounced. In this suction range the significantly lower moisture retention was reported in soils of bare plots over soils with plant population of 20000 and 8000 plants ha^{-1}.

Zahir *et al* (2013) studied the effects of soil amendments (gypsum, farmyard manure (FYM), gypsum + FYM and control), along with seed priming(seed soaked in water for 10 h

before sowing, and seed soaked in 0.4% gypsum solution for 10 h before sowing and a un-primed treatment as control) on soil properties of alkali soil in wheat crop. The priming methods were allocated to main plots and soil amendments sub-plots by using split plot design. They observed the effect of soil amendments and seed priming on soil properties such as soil pH and EC and SAR and they reported that the soil amendments lowered the soil pH significantly over control. The highest soil pH of 8.47 was reported in control and the lowest pH (7.94) in gypsum + FYM treatment and it showed 6.25% lower pH over control. The decrease in soil pH was more pronounced with combined application of gypsum and FYM along with seed priming of gypsum and it recorded lowest soil pH (7.83) over un-primed seeds (7.57). the combined application of gypsum and FYM alone or in combination with seed priming (gypsum 0.4%) also reported remarkable decrease in soil EC (1.39 dS m^{-1}). The decrease in soil EC was 36% compared to the control alone or in combination with un-primed treatment (2.79 dS m^{-1}). Sodium adsorption ratio (SAR) showed a non-significant difference with respect to seed priming and soil amendment but the soil amendments along with seed priming resulted decreased trend in soil SAR from 8.39 to 6.33 m mol per litre.

Mar *et al* (2000) conducted an experiment using RCBD design with two factors. One was, soil inoculation of three *Arbuscular mycorrhizal* isolates (*Glomus mosseae*, *Glomus deserticola* and natural *Arbuscular mycorrhizal* fungi) along with non-mycorrhizal treatment as control. The second factor was seed application of three free-living microbial inoculants (*Azospirillum*, *Pseudomonas* and *Trichoderma*) and uninoculated treatment. They also studied the interactions between *AM* and other bio-inoculants and their effects on microbial population and enzyme activities in the rhizosphere soil of maize plants. They reported that *AM* and all microbial inoculants had beneficial effect on growth and health of plant. They further reported that none of the free-living inoculants does not affect the percent colonization of AM. The highest *Azospirillum* population (5.5×10^7 cfu g^{-1} soil) were found in soil inoculation with AM isolates than non-mycorrhizal plants (5.0×10^7 cfu g^{-1} soil), but *Pseudomonas* and *Trichoderma* have negative effect (4.2 and 4.0×10^7 cfu g^{-1} soil respectively). The population of *Pseudomonas* and *Trichoderma* didn't affect by any treatments. They further reported that soil enzyme activities (esterase, phosphatase, trehalase and chitinase) were significantly higher in *Arbuscular mycorrhizal* inoculated soil, but *Pseudomonas* and *Trichoderma* have negative effect on esterase and phosphatase activity, *Trichoderma* on trehalase and chitinase activity and neutral effect showed by *Azospirillum* on all above soil enzyme activities.

Naseby *et al* (2000) conducted a pot experiment to study the effect of biocontrol strains on soil microbial communities and soil enzymatic activities. The treatments comprise of soil inoculation of *Pythium ultimum* and without inoculation as one factor and dipping of

pea seeds in sterile guar gum containing *Trichoderma* and pea seeds dipped only in sterile guar gum (control) as another factor. They reported that *Pythium* inoculation reduce the emergence of pea seedlings and recorded only 93% of germination, but *Pythium* effect was significantly reduced by the *Trichoderma*. Which it recorded 95% germination. *Trichoderma* significantly reduced the number of lesions caused by *Pythium*. They further reported that the higher enzyme activities were found in soil infected with *Pythium* and *Trichoderma* inoculation significantly reduced the effect of *Pythium* and recorded reduced b-glucosidase (5.4 PNP g^{-1} h^{-1}), NAGase (0.13 PNP g^{-1} h^{-1}) and chitobiosidase (2.21 PNP g^{-1} h^{-1}) activities compared to the *Pythium* control (6.52, 0.21 and 3.02 PNP g^{-1} h^{-1} respectively). *Trichoderma* also recorded lower alkaline phosphatase (0.39 PNP g^{-1} h^{-1}) and urease activities (1.15 g ammonia g^{-1} h^{-1}) relative to the *Pythium* control (0.22 PNP g^{-1} h^{-1} and 1.52 g ammonia g^{-1} h^{-1} respectively).

2.4 Effect of seed priming and plant spacing on economic feasibility

Elgailani *et al* (2015) study the effect of seed priming and micro dosing of fertilizer on yield and economic profitability of various crops such as sorghum, groundnut, sesame and cowpea. The experiment comprises of two priming and three micro-dose fertilizers applied to each plant in hole (0.3g, 0.6g and 0.9 g $plant^{-1}$ respectively). The experiment was undertaken to assess economic performance of the various treatments. The highest returns were obtained under seed priming in all the crops when micro-fertilizer was applied. The application of 0.9 g fertilizer to each hole along with seed priming increase the gross return of sorghum from Rs. 737 to Rs.1931 ha^{-1}, where the non-priming treatment with application of 0.9 g fertilizer showed increased net revenue from Rs. 458 to Rs. 649 ha^{-1}. In groundnut, the net benefit was raised from Rs. 14403 to Rs. 20986 ha^{-1} by priming with the application of 0.9 g fertilizer per hole. Priming with micro-dosing reported higher return compared to non-priming with micro-dosing. Compared to other crops the increment in revenue was much higher in groundnut with micro-dosing and seed priming. In sesame the gross return was raised from Rs. 794 ha^{-1} to Rs. 1757 ha^{-1} by combined application of priming and 0.3 g fertilizer dosing, but in cowpea with the application of 0.6 g fertilizer per hole combined with seed priming increase the gross margin from Rs. 863 to Rs. 1204 ha^{-1} over control. Fertilizer use efficiency (FUE) and value cost ratio (VCR) for grain yield and biological yield were maximum under treatment combinations in all crops and the increase in gross terurn from treatment combinations (seed priming and micro-dosing) the control treatment was Rs. 3473, 708, 593 and 748 ha^{-1} for groundnut, sorghum, cowpea and sesame, respectively.

Sharma *et al* (2014) found superior performance of *Rhizobium* compared to control with different fertility levels and biofertilizers on nutrient content, absorption and on quality of groundnut. The experiment consisting of 0, 50, 75 and 100% fertilizer level treatments and

four biofertilizer seed treatments such as control, *Rhizobium*, PSB and AM with RDF of 20 kg N ha^{-1} through urea and 60 kg P_2O_5 ha^{-1}, cultivated RG-382 variety at row spacing 45 cm. Their study showed that higher dose of above mentioned fertilizer significantly improves the P concentration in kernel. The highest net return of Rs.43717 was recorded in *rhizobium* treated crop followed by PSB and VAM and least in control (Rs.34637).

Yenagi *et al* (2017) confirmed the effect of plant spacing on dry pod and kernel yield of groundnut that, the plant spacing 30 cm x 10 cm produced 21.36 % higher dry pod yield and 29.69% higher kernel yield over a plant spacing of 30 x 20 cm (29.27 q dry pod yield and 21.25 q kernel yield ha^{-1} respectively). The plant spacing of 30 cm x 10 cm produced significantly higher net returns (Rs. 99,673 ha^{-1}) and B:C (2.84) as compared to other plant spacing of 30 cm x 20 cm (Rs. 67,059 ha^{-1} and 2.34). Even though the number of branches $plant^{-1}$, pods, dry pod weight $plant^{-1}$, shelling percent, sound mature kernels and 100 kernel weight were higher under 30 cm x 20 cm spacing but it was not exhibited higher yield per unit area.

Howlader *et al* (2009) reported net benefit and B:C in different plant spacings such as three inter plant spacings (20 cm, 30 cm and 40 cm) and three intra plant spacings (10 cm, 15 cm and 20 cm) respectively. The highest net return of Rs.47105 (considering seed cost only) obtained in the 40 cm × 20 cm plant spacing. Where the least net return came from 20 cm × 15 cm crop geometry. The same results were recorded in B:C analysis that the higher BCR of 19.67 (in terms of seed cost only) achieved in 40 cm × 20 cm crop geometry and least BCR (3.0) in 20 cm × 15 cm crop geometry.

Scott *et al* (2011) examined the consequence of row pattern and seeding rate effects on agronomic, disease and economic aspects in groundnut. The effect of two row patterns (single and twin rows) and three seeding rates (single row equivalents of 17, 20, and 23 seed m^{-1} of row) were allotted to main and sub plot in spilt plot design respectively. The both highest (54.17 q ha^{-1}) and lowest yield (47.72 q ha^{-1}) were recorded in twin and single row pattern with 23 seeds m^{-1} spacing respectively. Whereas the same results also noticed in case of net profit gained from the crop (Rs.106145 ha^{-1} and Rs. 92430 ha^{-1}) in twin and single row pattern with 23 seeds m^{-1} spacing respectively.

CHAPTER III

MATERIAL AND METHODS

The field experiment entitled with "Effect of seed priming and plant spacing on the growth, productivity and soil health of spring groundnut (*Arachis hypogaea* L.)" was carried out at Students' Research Farm, Department of Agronomy, PAU, Ludhiana during *spring* season 2018 and 2019, respectively.

3.1 Location and climate

Ludhiana is located in Trans-Gangetic Agro-Climatic zone, representing the Indo-Gangatic alluvial plain at 30^0 56' N latitude and 75^0 52' E longitude and at an elevation of 244 m above MSL (mean sea level). Ludhiana is categorized by sub-tropical, semi-arid type of climate with warm summers and very cold winters. The usual maximum (max.) and minimum (min.) temperature illustrate substantial dissimilarities during summer and winter. The max. temperature of more than 38 ^{0}C is common in summer and regular frosty spells are experienced throughout winter season, predominantly in December and January. The mean annual rainfall is 705 mm, roughly 80% of which is received in between July to September during monsoon season.

3.2 Weather during crop season

The weather information obtained from the Department of Climate Change and Agricultural Meteorology, PAU, Ludhiana throughout the crop period of year 2018 and 2019 (*spring*). It is presented in figure 3.1 and appendix-I. The mean temperature (weekly) noted throughout the crop season from second week of March, 11th SMW (12-18 March) to first week of July, 27th SMW (2-8 July) of the year 2018 and 2019 respectively. The average temperature lies between 22^0 C and 17.7^0 C in 11th SMW to 29.9^0 C and 33.1^0 C in 27th SMW during the year 2018 and 2019 respectively. The minimum weekly temperature fluctuated between 14.1^0 C and 10.7^0 C in 11th SMW to 26^0 C and 28.5^0 C in 27th SMW for both the years 2018 and 2019. Whereas the maximum weekly temperature lies between 29.9^0 C and 24.6^0 C in 11th SMW (12-18 March) to 33.9^0 C and 37.6^0 C in 27th SMW (2-8 July) respectively. The RH (relative humidity) during the same period varied from 33-86 and 42-90 percent in the morning and 9-62 and 15-48 percent at evening, the maximum being in 11th SMW and 27th SMW and minimum being in 21st SMW (21-27 May) and 18th SMW (30 April – 06 May). The amount of rainfall received during the crop season was about 223.6 mm and 105.9 mm against 229 mm of normal rainfall. Evaporation during same period was 1090 mm and 1050 mm in both years 2018 and 2019 respectively, over a normal evaporation of 868.3 mm and 832.1 mm during above mentioned years respectively. The daily sunshine hours ranged from 10 hours and 7.5 hours in 11th SMW (12-18 March) and 6.9 hours and 5.5 hours in 27th SMW (2-8 July) during the year 2018 and 2019 respectively.

3.3 Characteristics of the soil

The representative soil samples previously collected from the experimental field at various depth (0-15 cm) from eight randomly selected spots and a composite sample was made before initiating the experiment. The soil sample were air dried, grinded, sieved and finally subjected to physical and chemical analysis to determine the soil properties and it was presented in table 3.1.

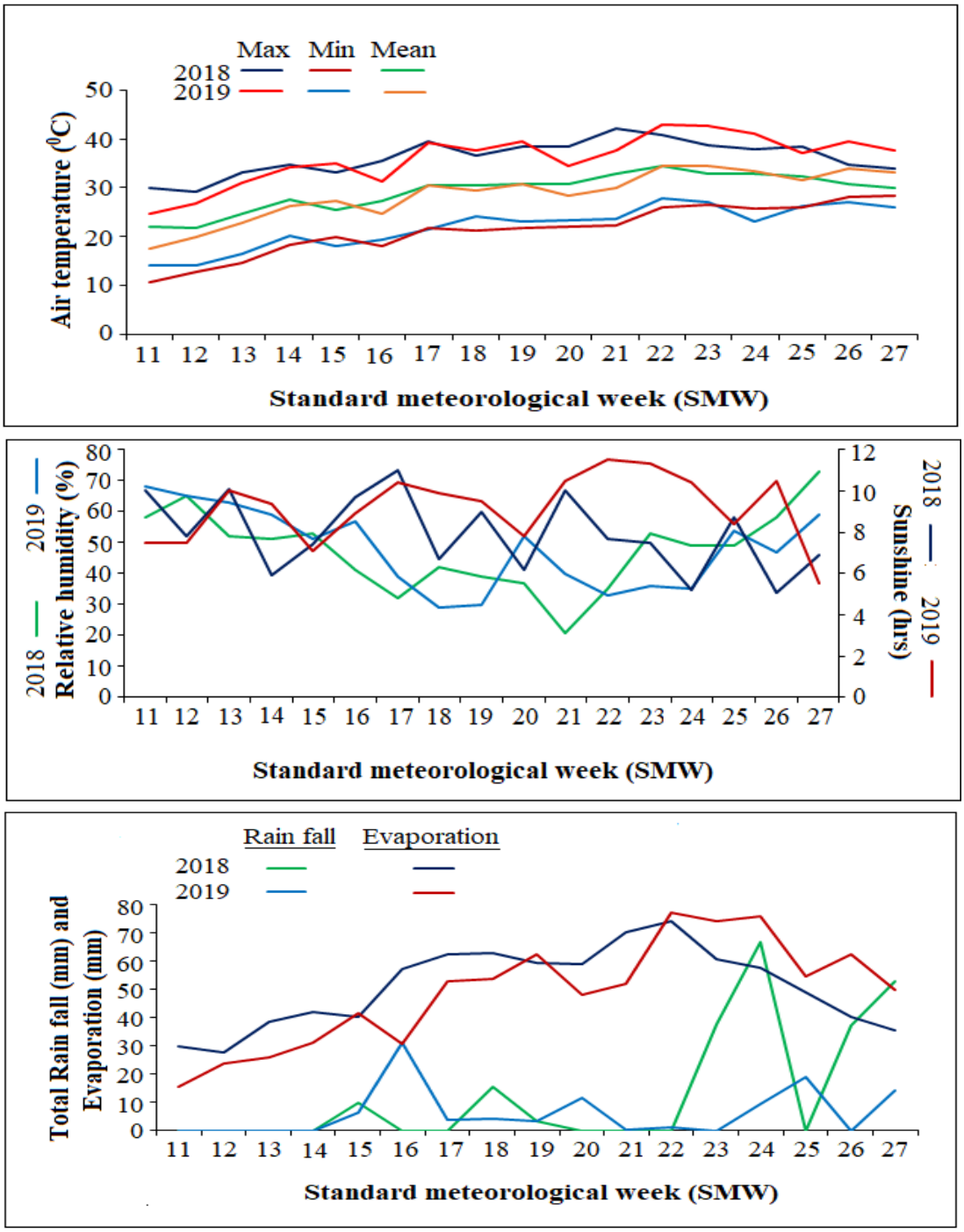

Figure 3.1 Weekly mean meteorological data recorded during the crop season spring (2018 and 2019) at Meteorological Observatory, PAU, Ludhiana

Table 3.1 Physico-chemical characteristics of the soil (0-15 cm depth)

Parameter	Year		Rating	Analytical method employed
	2018	2019		
pH (1:2, soil:water)	7.46	7.49	Neutral	Blackman's glass electrode pH meter (Jackson 1967)
EC (1:2, soil:water) (dS m^{-1})	0.23	0.23	Normal	Conductometer method (Jackson 1967)
Organic carbon (%)	0.30	0.29	Low	Walkely and Black's (1934) rapid titration method
Available N (Kg ha^{-1})	121.5	119.2	Low	Alkaline $KMnO_4$ method (Subbiah and Asija 1956)
Available P (Kg ha^{-1})	20.8	21.6	Medium	Colorimetric Method (Olsen *et al* 1954)
Available K (Kg ha^{-1})	124.6	127.2	Low	1N NH_4OAc extractable K (Piper 1966)

3.4 Cropping history of the field

Cropping history of three years before the experimental crop with different seasons namely Kharif, Rabi and Spring was given in table 3.2.

Table 3.2 Cropping history of the field

Year	Crop season		
	Kharif	***Rabi***	***Zaid***
2015-16	Soybean	Wheat	Fallow
2016-17	Soybean	Wheat	Fallow
2017-18	Fallow	Fallow	Groundnut
2018-19	Fallow	Fallow	Groundnut

3.5 Experimental detail

Name of the experiment: Effect of seed priming and plant spacing on the growth, productivity and soil health of spring groundnut (*Arachis hypogaea* L.)

Location: Students' Research Farm, Department of Agronomy, PAU, Ludhiana.

Treatments

A: Main plots - Spacing (R-R & P-P)

G_1: 22.5 cm × 20.0 cm

G_2: 30.0 cm × 15.0 cm

G_3: 45.0 cm × 10.0 cm

B: Sub plots (Seed primer)

T_1: Consortium bio fertilizer (*Rhizobium sp* LSMR-1 and *Rhizobacterium* RB-3)

T_2: Cow urine

T_3: Vermicompost

T_4: Vermiwash *

T_5: Consortium of bio fertilizer + Cow urine + Vermicompost + Vermiwash

T_6: Control

*(400 ml indigenous cow urine + 225 g Vermicompost + 110 g jaggery)

Total number of treatments	: 18
Number of replications	: 4
Number of plots	: 72
Variety	: TG37A
Experimental design	: Split plot design

The experiment was carried-out in a split plot design by replicating four times with different plant spacing combined with various seed priming materials, such as consortium of bio fertilizer, cow urine, vermicompost, vermiwash, combination of all above materials and control. The crop was sown on 15th March during both years 2018 and 2019 and harvested on 5th July with respective of their years. A uniform recommended dose of fertilizers (RDF), 15 kg N, 20 kg P_2O_5, 25 kg K_2O from 32.6 kg Urea, 125 kg SSP, 41.5 kg MOP and 125 kg Gypsum ha^{-1} were applied in each experimental units and irrigation was given periodically as per crop requirement. The plot size of 11.4 m × 9 m were used for all three planting geometries G_1, G_2 and G_3 respectively among main plots and among sub plots, gross plot size of 5.4 m × 2.7 m and net plot size of 4.4 m × 2.4 m ,4.4 m × 2.1 and 4.4 m × 1.8 m were used for all three crop geometries (plant spacing) G_1 (22.5 cm × 20.0 cm), G_2 (30.0 cm × 15.0 cm) and G_3 (45.0 cm × 10.0 cm respectively. The layout plan of experimental field was represented in Fig. 3.2.

3.6 Cultural operations

3.6.1 Land preparation

The experimental field was harrowed by disc harrow followed by cultivator and then planking. In levelled field experimental plots, irrigation channels and bunds were made as per experimental layout.

3.6.2 Fertilizer application

Fixed dose of nitrogen, phosphorus and potassium (N: P_2O_5: K_2O @ 15: 20:25 kg ha^{-1}) along with 125 kg of gypsum ha^{-1} fertilizers were broadcasted at the time of sowing by taking 47.5g of Urea, 182.25g of SSP, 60.5g MOP and 182.25g Gypsum to each experimental unit.

3.6.3 Seed rate, spacing and sowing

The healthy seeds (kernel) of spring groundnut variety TA37A with seed rate 80 kg of kernels per hectare were used for sowing by dibbling method. The plant spacing was maintained as per the mentioned crop geometry of 22.5 cm × 20.0 cm, 30.0 cm × 15.0 cm and 45.0 cm × 10.0 cm. Groundnut seeds were primed with different seed priming materials before sowing and sowing was done on March 15th during year for *spring* 2018 and 2019.

3.6.4 Thinning and gap filling

The non-emerged crop area was reseeded after complete field emergence of spring groundnut and thinning was taken at one-two true leaf stage of the crop to keep optimum plant population in each plot.

3.6.5 Hoeing and weeding

The field was kept weed free with manual hoeing. Two hoeing's at 3 and 6 weeks after sowing of the crop were taken to control weeds.

3.6.6 Irrigation

The spring groundnut require 4-5 irrigation during the growing season of the crop. Four irrigations were applied to the crop as per its requirement at different periods up to harvest. The details of irrigation are given in table 3.3.

Table 3.3 The date and depth of irrigation

Irrigation details			
Year	**Irrigation No.**	**Date of irrigation**	**Depth of irrigation (cm)**
2018 (*Spring*)	1st	30th March	4
	2nd	16th April	5
	3rd	7th May	5.6
	4th	20th May	5.6
2019 (*Spring*)	1st	28th March	4.5
	2nd	10th April	5.0
	3rd	26th April	5.8
	4th	30th May	5.4

3.6.7 Plant protection measures

The threat of hairy caterpillar was observed during vegetative period of crop. It was controlled by spraying of Ekalux 25EC (Quinalphos) at 1.25 litre ha^{-1} in 150-200 litres of water with manually operated knapsack sprayer.

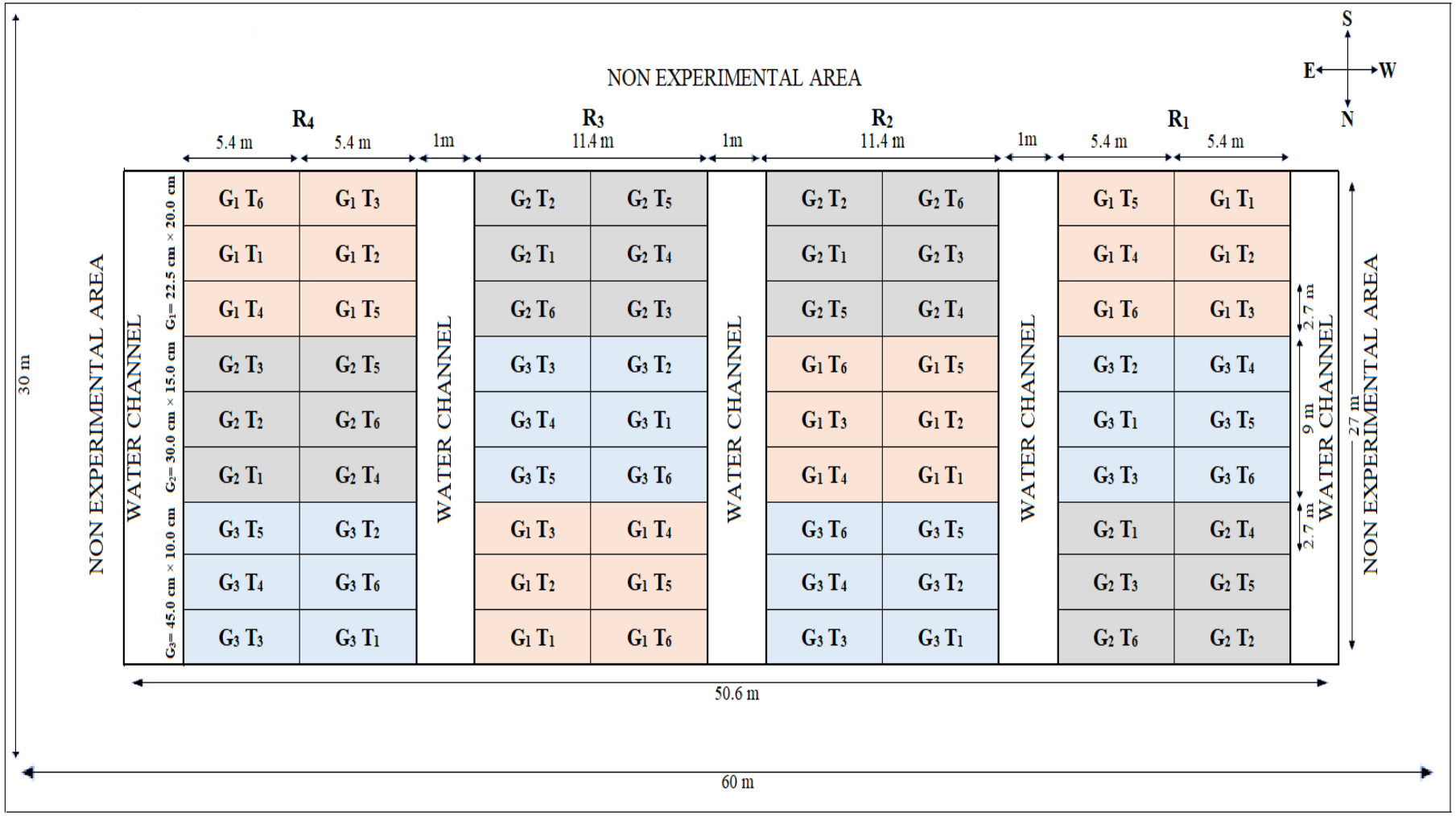

Figure 3.2 Layout plan of experimental field

3.6.8 Harvesting and threshing

The crop was manually harvested at its physiological maturity stage on 5th July during both the years 2018 and 2019. The border lines were harvested and kept them outside, to make the net plot size. The tagged plants were harvested separately to record various postharvest parameters and their yield was added to the final net plot yield. The weight of biological yield from each plot was recorded and then threshing and cleaning operations were done to record the pod yield and haulm yield respectively.

3.7 Seed priming

3.7.1 Seed priming with Consortium bio-fertilizer (T_1)

Seed were primed using water by dipping the 1 kg of groundnut kernels for 6 hours in 2 litres of water and then seeds were taken out and treated with Consortium bio-fertilizer followed by shade drying on gunny bag before sowing in field.

3.7.2 Seed priming with cow urine (T_2)

Seed were primed using indigenous cow urine by dipping the groundnut kernels in solution by dissolving 800 ml of cow urine in 2 litres of water for 1 kg of groundnut kernels for 6 hours and then seeds were taken out and shade dried on a gunny bag before sowing in field.

3.7.3 Seed priming with vermicompost (T_3)

Seed were primed using water and dipping the groundnut kernels in 2 litres of water for 1 kg of seeds for 6 hours and then seeds were taken out. The solution of jaggery (dissolving 220g of jaggery in 2 litres of water for 1kg seeds) was sprinkled on seeds followed by treating seeds with 450g of fine vermicompost per kg seeds and then shade dried on a gunny bag before sowing in field.

3.7.4 Seed priming with vermiwash (T_4)

Seed were primed by dipping the groundnut kernels in solution (dissolving 800ml of cow urine, 450g vermicompost and 220 of jaggery in 2 litres of water and kept it for 6 hours). Filtrate was extracted and seeds were dipped in 2 litres of filtrate for 1 kg of groundnut kernels for 6 hours and then seeds were taken out and shade dried on a gunny bag before sowing in field.

3.7.5 Seed priming with Consortium bio-fertilizer+ cow urine +vermicompost + vermiwash (T_5)

Seed were primed by dipping the groundnut kernels in solution (2 litres vermiwash filtrate + 800 ml of cow urine) for 6 hours. Seeds were removed out and thoroughly mixed with 225g of vermicompost and Consortium bio-fertilizer followed by shade drying on a gunny bag before sowing in field.

3.7.6 Control (T_6)

Non-primed seeds were seeded in control treatment

3.8 Observations recorded

3.8.1 Growth parameters

3.8.1.1 Emergence count (Plants m^{-2})

The emergence count was started to take at first plant appearance in the field and recorded up to complete appearance of seedlings from one m^2 randomly selected area in each plot.

3.8.1.2 Plant height (cm)

Plant height was recorded from the base i.e. ground level to the tip of the terminal bud on main shoot of the randomly (tagged) selected plants from every plot at 30, 60, 90 DAS and at harvest. The average plant height was calculated and articulated in centimetres.

3.8.1.3 Number of shoots (No.)

All the primary shoots arising from the main shoot of the plant were counted as from the selected five plants in each plot at 30, 60, 90 DAS and at harvest. The average value of five plants were computed and noted.

3.8.1.4 Leaf area index (LAI)

Leaf area of groundnut was noted from the two randomly selected places in each plot at 30, 60, 90 DAS and at harvest by leaf area mater. It was computed taking into account, the area occupied by each plant as per the following formula (Watson 1953).

$$\text{LAI} = \frac{\text{Total leaf area}}{\text{Unit leaf area}}$$

3.8.1.5 Dry matter accumulation (g $plant^{-1}$)

The accumulated dry matter in plant was recorded at 30, 60, 90 DAS and at harvest by taking two plants randomly from each plot. The above ground biomass was sun dried for two days and oven dried at 60-65^0 C for two days and expressed in ‘g’ per plant.

3.8.1.6 Days to 50% flowering

The number of days required by 50 percent of the plants in each plot to bear flowers, was observed from the initiation of first flower on the plants and recorded.

3.8.1.7 Number of nodules $plant^{-1}$

Number of nodules per plant were counted from randomly selected plants at 50% flowering and the mean value was computed and expressed as number of nodules $plant^{-1}$.

3.8.2 Yield and yield attributes

3.8.2.1 Number of pegs plant^{-1}

The number of pegs produced by each plant (tagged) was recorded at the time of harvesting by counting the total number of pegs including pods and average number of pegs plant^{-1} was recorded.

3.8.2.2 Number of pods plant^{-1}

Number of matured and immature pods plant^{-1} from the randomly selected (tagged) plants were harvested and counted from each plot. The mean value was noted and expressed as number of pods plant^{-1}.

3.8.2.3 Number of filled pods plant^{-1}

Number of sound matured pods from tagged plants were separated and counted. The average value was expressed as number of filled pods plant^{-1}.

3.8.2.4 Pod weight (g plant^{-1})

Pod weight from the five tagged plants were separated and sundried. The mean value of pods ware taken and expressed as pod weight plant^{-1} in 'g'.

3.8.2.5 Number of kernels pod^{-1}

The number of kernels in each pod was noted by counting number of pods in one kilogram of sundried pods from each treatment, kernels are separated and counted. The average of kernels expressed as kernels per pod.

3.8.2.6 100 Kernel weight (g)

The weight of randomly drawn hundred kernels from the composite sample from each of the net plot area, weighed and expressed in 'g'.

3.8.2.7 Shelling percentage (%)

Shelling percentage one kilogram of sundried pods were collected from composite sample from each net plot area, which were shelled and weight of the kernels was recorded. The shelling percentage was calculated by dividing the weight of the kernels with known weight of pods taken and expressed in percentage.

$$\text{Shelling percentage (\%)} = \frac{\text{Weight of kernels (g)}}{\text{Dry weight of pods (g)}} \times 100$$

3.8.2.8 Pod yield (q ha^{-1})

Pods from the net plot area were separated from haulms, sun dried till constant weight was attained and expressed in quintal ha^{-1}

3.8.2.9 Haulm yield (q ha^{-1})

After the removal of pods from the plants in the net plot area, haulm was sun dried until the constant weight was attained and haulm yield was recorded and expressed in quintal ha^{-1}.

3.8.2.10 Biological yield (q ha^{-1})

The weight of sundried above and below ground plant parts of each plot was recorded before threshing and expressed as quintal ha^{-1}.

3.8.2.11 Harvest index (HI)

The harvesting index is the ratio of economical yield to biological yield. The harvesting index of crop is calculated by using the below formula and expressed in percentage.

$$HI = \frac{\text{Economical Yield}}{\text{Biological Yield}} \times 100$$

3.8.3 Quality analysis

3.8.3.1 Oil content (%)

The kernel oil content was estimated by Nuclear Magnetic Resonance (NMR) spectroscope technique and expressed in percentage (%).

3.8.3.2 Protein content (AOAC 2000)

The nitrogen content in kernels was determined by using Kjeldhal method and converted into protein by multiplying factor 6.25 to nitrogen content and expressed in percentage.

3.9 Plant analysis

3.9.1 Sampling and preparation of plant samples

The sample of groundnut plants were taken at harvest, sun dried for two days and then oven dried for 24 hours at 60^0 C. The samples of haulm and kernels were fine grind and then analysed for total nitrogen, phosphorus and potassium separately.

3.9.1.1 Estimation of nitrogen

The determination of total nitrogen was done by digesting 0.5 g samples with 10 ml concentrated H_2SO_4 along with digestion mixture in Kjeldhal's digestion unit as proposed by Jackson (1967) for both haulm and kernels separately. The total nitrogen uptake by plant was expressed in percentage and kg ha^{-1} by taking mean value of both haulm and kernels.

3.9.1.2 Estimation of phosphorus

The phosphorus was analysed by digesting 0.5 g samples in triple acid mixture of HNO_3:$HClO_3$:H_2SO_4 in the ratio of 9:3:1. The digested aliquot was resolved by Vanadomolybdo- phosphoric yellow colour technique in HNO_3 and the intensity of yellow colour was read at 470 nm for both haulm and kernels separately in an Elico spectrophotometer model CL 24 as suggested by Jackson (1967).

3.9.1.3 Estimation of potassium

Potassium content in plant acid extract was assessed by using the flame photometer. Reading was taken after digesting the samples with tri or diacid mixtures for both haulm and kernels as suggested by Jackson (1967) separately.

3.10 Soil analysis

Soil samples were taken from 0-15 cm depth, followed by shade drying, grinding and sieving (2 mm sieve). The pH, electrical conductivity (dS m^{-1}), available nitrogen, phosphorus and potassium content of samples were analysed. The fresh soil samples were collected at flowering stage of the crop and used for the analysis of dehydrogenase and alkaline phosphatase enzymatic activity.

3.10.1 Textural analysis

The soil sample were collected layer wise from 0-15 cm and 15-30 cm depths randomly from five different spots of experimental field. The samples of respective depths were composited and the mechanical analysis was done by International pipette method given by Piper (1966) and the results are presented in table 3.4.

Table 3.4: Textural composition of the soil

Soil depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural class
0-15	81.9	5.9	12.2	Loamy sand
15-30	80.8	7.2	12.0	Loamy sand

3.10.2 Soil physical constants

The physical soil constants were determined for different layers and prescribed in table 3.5.

Table 3.5: Single value physical constants

Soil depth (cm)	Suction value at 0.3 bar (cm)	% (w/w)	Suction value at 15 bar (cm)	% (w/w)	Bulk density (g cm^{-3})
0-15	2.69	11.31	0.90	3.77	1.61
15-30	2.64	11.10	1.03	4.28	1.60
Total	5.33	-	1.93	-	-
Method employed	Pressure plate apparatus (Richards and Weaver (1943)	-	Richards and Weaver's (1943) Pressure plate apparatus	-	Core sampler method (Bodman 1942)

3.10.3 Microbiological analysis

3.10.3.1 Dehydrogenase activity

The soil dehydrogenase enzyme activity was analysed by using standard protocol specified by Casida *et al* (1964) and articulated in 'µg of TPF released 'g^{-1} of soil h^{-1}'.

3.10.3.2 Alkaline phosphatase activity

Alkaline phosphatase enzyme activity (EC 3.1.3.2) was analysed by the method given by Tabatabai and Bremner (1969) and expressed in 'µg of PNP per gram of soil per hr'.

3.10.3 Chemical studies

3.10.3.1 Available Nitrogen

Determination of available soil nitrogen content was done by using modified alkaline potassium permanganate method as delineated by Subbiah and Asija (1956) and was expressed in kg ha^{-1}.

3.10.3.2 Available Phosphorus

The available soil phosphorus was analysed by 0.5 N sodium bicarbonate extractable P by Olsen *et al* (1954) method in spectrophotometer and was expressed in kg ha^{-1}.

3.10.3.3 Available Potassium

The available soil potassium was determined by using 1 N ammonium acetate extractable K (Piper 1966) in Flame Photometry and was expressed in kg ha^{-1}.

3.11 Economic

3.11.1 Gross returns (₹ ha^{-1})

The gross income in terms of '₹ ha^{-1}' was obtained by multiplying groundnut pod and haulm yield from each treatment with present market price. The market prices are presented in appendix-II.

3.11.2 Net returns (₹ ha^{-1})

The net outcome from every treatment was worked out by subtracting the total cost of production from the gross outcome.

3.11.3 Benefit cost ratio (BCR)

The benefit cost ratio was calculated using the following formula:

$$\text{BCR} = \frac{\text{Gross return (₹ ha}^{-1}\text{)}}{\text{Total cost of cultivation (₹ ha}^{-1}\text{)}}$$

3.11 Statistical analysis

The data collected on various growth, yield and yield attributes and quality parameters were statistically analysed by using CPCS software. Experimental data was analysed according to standard statistical method for Split plot design. The 5 percent level of

significance was used to compare all treatments. The analysis of varience (ANOVA) for split-plot design was given below:

Table 3.6 Analysis of varience

Source of variation	**Degrees of freedom**
Replications	3
Plant spacing (A)	2
Error (a)	6
Seed priming (B)	5
Plant spacing × Seed priming	10
Error (b)	45
Total	71

CHAPTER IV

RESULTS AND DISCUSSION

The field experiment entitled "Effect of seed priming and plant spacing on the growth, productivity and soil health of spring groundnut (*Arachis hypogea* L.)", was carried out for two years at Students' Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana during spring season 2018 and 2019. The results of the experiment are presented and discussed in this chapter under the following headings.

4.1 Growth parameters

4.2 Yield and yield attributes

4.3 Quality analyses

4.4 Economics

4.5 Plant analyses

4.6 Soil analyses

4.1 Growth parameters

4.1.1 Emergence count (Plants m^{-2})

The emergence count in order to analyse the effect of different treatments particularly seed priming and plant spacing on field emergence (plants m^{-2}) was recorded upto complete emergence and presented in Table 4.1. During the year 2018, the maximum emergence was observed (16.2 plants m^{-2}) under G_1 plant spacing, which was at par with other two plant spacings G_2 and G_3.

A similar trend in crop emergence under various plant spacings (crop geometry) during the year 2019 and in pooled data of two years, 16.3 plants m^{-2} were observed under same plant spacing (G_1) and it was at par with other plant spacings.

Among seed priming during the year 2018, significantly higher emergence (20.6 plants m^{-2}) was found in spring groundnut when seed primed with consortium bio-fertilizer. During the year 2019 and in pooled data of two years, 20.2 and 20.4 plants m^{-2} were found in consortium bio-fertilizer seed primed spring groundnut crop respectively, which was significantly higher than the control (without priming) spring groundnut crop and were found to 14.1, 13.8 and 14.0 plants m^{-2} during 2018, 2019 and in pooled data of two years respectively.

Even though the plant spacings were different, the plant density per unit area (22.2 plants m^{-2}) was kept constant, to evaluate the performance of spring groundnut under various crop geometries. The germination of any crop usually influenced by genetic characters of the seed, period of seed dormancy and some environmental and management practices such as atmospheric temperature, soil moisture, sowing depth of the seed and seed priming but not

affected by plant spacing. The similar results in groundnut were reported by Alam *et al* (2002). They reported that, when crop was raised under 22.4 cm × 22.4 cm and 30 cm × 16.7 cm plant spacings, on an average 19 plants m^{-2} were found under both plant spacings. They further reported that, the crop emergence in field was influenced by the genetic potential of the seed, stored seed material and available soil moisture and not by plant spacing.

Among seed priming, the enhanced crop emergence is due to growth promoting action of consortium bio-fertilizer and reduction of high seed moisture after seed soaking at low atmospheric temperature. The inhibitory action of cow urine on seed germination was also one of the reasons for lower germination in cow urine primed seeds. These results were in accordance with the findings of Foley (1994), who reported that germination of oat was highly dependent on temperature and moisture content of the seed. They further reported that high seed moisture (>16%) and low temperature (<20 ^{0}C) recorded 64% germination compared to low seed moisture (14%) and slightly high temperature (30 ^{0}C) which recorded 84% germination in oat.

Table: 4.1 Effect of seed priming and plant spacing on emergence of spring groundnut

Treatments	**Emergence (plants m^{-2})**		
	2018	**2019**	**Pooled**
Plant spacing			
G_1- 22.5 cm × 20.0 cm	16.2	16.3	16.3
G_2- 30.0 cm × 15.0 cm	15.9	16.1	16.0
G_3- 45.0 cm × 10.0 cm	15.7	15.9	15.8
CD (p=0.05)	NS	NS	NS
Seed priming			
T_1- Consortium bio-fertilizer	20.6	20.2	20.4
T_2- Cow urine	14.2	14.6	14.4
T_3- Vermicompost	15.7	16.2	15.9
T_4- Vermiwash	14.5	14.4	14.5
T_5- Con.bio + C.urine+ V.comp+ V.wash	16.6	17.3	17.0
T_6- Control	14.1	13.8	14.0
CD (p=0.05)	0.60	0.85	0.6
Interaction	1.04	1.47	1.04

Kishore *et al* (2005) also observed that, due to production of auxin in groundnut by phylloplane bacteria (*Bacillus firmis* GRS 12) after seed priming influences the seedling

emergence upto 98% over control (82%). Similarly, Doak (1954) reported inhibitory effect of cow urine on white clover seed emergence, which recorded 60% and 82% germination after 66 h and 93 h respectively, which was the lowest compared to control. Control treatment recorded 73% and 89% germination after 66 h and 93 h respectively. They further reported that seed priming with cow urine increases the osmotic pressure of seed for a short period and inhibits seed germination.

The interaction effects of seed priming and plant spacing was found to be significant during the crop period and it was presented in Table 4.2.

Interactional effect

The perusal of data in Table 4.2 revealed that spring groundnut raised under G_1 plant spacing reported significantly higher emergence (plants m^{-2}) when seed primed with consortium bio-fertilizer than other seed priming treatments. Significantly lower crop emergence was observed when spring groundnut was seed primed with cow urine, which was at par with control. It was observed in sequence $T_1 > T_5 > T_3 > T_4$ in plant spacing G_1. The similar trend was observed in all seed primed treatments in G_2 and G_3 during crop season 2018, 2019 and in pooled data of two years, respectively. The highest emergence was found in G_1 when seed primed with consortium bio-fertilizer (except cow urine and control). The results showed that the emergence was completely depended on seed priming rather than plant spacing. The similar results were reported by Murungu *et al* (2004), they reported that increased plant stand of maize was due to early initiation of germination process in primed crop and it was 14% higher germination over non-primed maize.

Table: 4.2 Interactional effect of seed priming and plant spacing on emergence of spring groundnut

Treatments	**2018**			**2019**			**Pooled**		
Seed priming / Plant spacing	**G_1**	**G_2**	**G_3**	**G_1**	**G_2**	**G_3**	**G_1**	**G_2**	**G_3**
T_1- Consortium bio-fertilizer	21.7	20.4	19.9	21.4	20.6	18.7	21.6	20.5	19.3
T_2- Cow urine	15.0	14.7	14.2	13.9	13.7	13.4	14.3	14.1	14.0
T_3- Vermicompost	17.8	16.4	16.1	16.7	16.1	15.7	17.2	15.5	15.0
T_4- Vermiwash	15.7	15.0	14.3	14.9	13.9	13.7	15.3	15.0	14.5
T_5- Con.bio + C.urine+ V.comp+ V.wash	18.4	15.1	15.0	18.3	17.9	15.7	18.2	16.7	15.4
T_6- Control	12.8	12.4	12.2	13.9	13.4	13.2	14.2	13.4	12.9
CD (p=0.05)	1.04			1.47			1.04		

4.1.2 Plant height (cm)

The plant height has been a reliable index of growth and metabolic activities of the plants. It was observed periodically at monthly intervals and at harvest during both the years, to study the performance of spring groundnut to various seed priming and plant spacings and presented in Table 4.3.

A trend of sluggish growth rate in terms of plant height was observed from crop emergence to 30 days after sowing (DAS) under all crop geometries during both the years and in pooled data of two years.

During the year 2018, under all crop geometries which was well noticed that a little increment in plant height on an average of 5.22 cm was observed upto 30 DAS. Subsequently, from 30 to 60 DAS the increase in plant height to the tune of 20.2 cm and the increment was continued upto harvest. Finally, the increase in plant height from 90 DAS to harvest of the crop was on an average 13.0 cm. This showed that during initial phase of the crop upto 30 DAS, increment was less, maximum (20.2 cm) between 30 to 60 DAS, then it decreased 14.3 cm and 13.0 cm, respectively between 60 to 90 DAS & 90 DAS to harvest of crop.

During the year 2019 and in pooled data of two years, at early stages the increment in plant height was 5.21 cm and 5.22 cm upto 30 DAS, from 30 to 60 DAS it was about 17.6 cm and 18.9 cm and finally increase in plant height from 90 DAS to harvest of the crop was to the tune of 12.7 cm and 12.8 cm, respectively. The highest plant height 53.5 cm, 50.6.8 cm and 52.1 cm during 2018, 2019 and in pooled data of two years respectively, were observed under G_1 crop geometry at harvest stage, which was at par with other plant spacings G_2 and G_3 at each periodic date of observation.

Among different seed priming treatments, like plant spacing, similar trend in plant height was observed at all periodic stages of the crop. During 2019 and pooled data of two years, the seed primed with consortium bio-fertilizer, vermicompost & con.bio + c.urine+ v.comp+ v.wash treatments resulted higher plant height than other treatments at 30 DAS, 60 DAS & 90 DAS, but in 2018, it was also found to be significant under the same treatments than cow urine and control treatment. But, the maximum plant height at maturity was observed to be 54.7 cm, 51.1 cm and 52.9 cm during 2018, 2019 and in pooled data of two years, in consortium bio-fertilizer seed primed spring groundnut. But which was at par with other seed primed treatments during both the years except in pooled data of two years, with respect to plant height.

In pooled data of two years, the significantly higher plant height (52.9 cm) was noticed in consortium bio-fertilizer primed spring groundnut, which was at par with other treatments i.e. T_3, T_4 and T_5, but significantly higher over T_2 and T_6.

Table: 4.3 Effect of seed priming and plant spacing on periodic plant height (cm) of spring groundnut

Treatment	30 DAS			60 DAS			90 DAS			At harvest		
	2018	**2019**	**Pooled**	**2018**	**2019**	**Pooled**	**2018**	**2019**	**Pooled**	**2018**	**2019**	**Pooled**
Plant spacing												
G_1- 22.5 cm × 20.0 cm	5.31	5.38	5.34	25.8	23.3	24.6	40.5	37.6	39.1	53.5	50.6	52.1
G_2- 30.0 cm × 15.0 cm	5.19	5.20	5.20	25.4	23.0	24.2	39.5	37.0	38.3	52.5	49.9	51.2
G_3- 45.0 cm × 10.0 cm	5.16	5.05	5.11	25.0	22.1	23.6	39.0	36.9	37.9	52.0	49.0	50.5
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Seed priming												
T_1- Consortium bio-fertilizer	5.31	5.76	5.53	26.2	24.1	25.2	41.7	38.4	40.1	54.7	51.1	52.9
T_2- Cow urine	5.08	4.88	4.98	24.8	21.7	23.3	38.7	36.5	37.6	51.6	49.2	50.4
T_3- Vermicompost	5.27	5.40	5.33	25.7	23.6	24.7	41.3	38.0	39.7	54.3	50.7	52.5
T_4- Vermiwash	5.23	5.17	5.20	25.3	22.7	24.0	39.2	36.5	37.9	52.4	49.2	50.8
T_5- Con.bio + C.urine+ V.comp+ V.wash	5.24	5.29	5.26	25.5	23.4	24.4	40.5	37.5	39.0	53.5	50.2	51.8
T_6- Control	5.20	4.77	4.98	24.7	21.4	23.1	36.5	35.9	36.2	49.5	48.6	49.0
CD (p=0.05)	NS	0.50	0.32	NS	1.66	1.13	3.29	NS	2.32	NS	NS	2.19
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

The spring groundnut was sown under various plant spacings, but the area available to each plant for utilization of natural resources was same (0.045 m^2). Hence, no restriction was offered on plants for the utilization of natural resources such as space, sun light, moisture and nutrients etc. Therefore, even though the highest plant height reported G_1 (22.5 cm × 20 cm), which was at par with G_2 and G_3. These results were in accordance with the findings of Mundra *et al* (2010), they observed the highest plant height (28.5 cm) under 20 cm × 15 cm plant spacing than 30 cm × 10 cm plant spacing. They reported that, due to uniform availability of natural resources and proper plant growth, 20 cm × 15 cm plant spacing reported higher plant height over 30 cm × 10 cm plant spacing, even under identical plant density (33 plants m^{-2}).

Similarly, significantly higher plant height due to increased competition for the use of basic resources under *rhizobium* and PSB treatments over control in groundnut crop was reported by Singh *et al* (2011).

The interactional effect among plant spacing and seed priming was found to be non-significant.

4.1.3 No. of shoots plant^{-1}

The number of shoots per plant is an important index of plant canopy development for the production of higher yield attributes and ultimately pod yield in groundnut crop. The number of shoots plant^{-1} was monitored at monthly intervals and at harvest during both the years 2018, 2019 and it was presented in Table 4.4.

During 2018, it was observed at 30 DAS of the crop that, on an average 5.76 shoots plant^{-1} were recorded under various planting geometries. The increment in no. of shoots plant^{-1} from 30 to 60 DAS was on an average 4.08 which was the grand growth stage, but the further increment from 60 DAS to 90 DAS and from 90 DAS to harvest of the crop was very low. The highest no. of shoots plant^{-1} (12.0) at the time of harvesting were recorded in G_1 plant geometry, but these were at par with G_2 and G_3.

During the year 2019 and in pooled data of two years, a similar trend in the increment of no. of shoots plant^{-1} were observed. The increment was to the tune of 5.04 and 5.40 from emergence to 30 DAS, 3.07 and 3.58 from 30 to 60 DAS were reported respectively, under plant geometries. The further increment was very low, but the maximum no. of shoots to the tune of 11.6 and 11.9 plant^{-1} during 2019 and in mean data of two years respectively, were observed under G_1 plant geometry. Data depicts that the maximum no. of shoots plant^{-1} (11.6) under G_1 plant spacing at harvesting was at par with G_2 but significantly higher over G_3. In pooled data of two years a non-significant difference among all crop geometries was noticed.

Table: 4.4 Effect of seed priming and plant spacing on periodic no. of shoots plant^{-1} of spring groundnut

Treatment	30 DAS			60 DAS			90 DAS			At harvest		
	2018	**2019**	Pooled	**2018**	**2019**	**Pooled**	**2018**	**2019**	**Pooled**	**2018**	**2019**	**Pooled**
Plant spacing												
G_1- 22.5 cm × 20.0 cm	5.93	5.37	5.65	10.2	8.22	9.22	11.6	10.7	11.2	12.2	11.6	11.9
G_2- 30.0 cm × 15.0 cm	5.74	4.98	5.36	9.82	8.09	8.96	11.2	10.5	10.8	12.0	11.1	11.5
G_3- 45.0 cm × 10.0 cm	5.60	4.78	5.19	9.49	8.03	8.76	11.0	10.3	10.6	11.8	10.8	11.3
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.54	NS
Seed priming												
T_1- Consortium bio-fertilizer	5.44	4.58	5.01	8.67	7.44	8.06	9.80	10.1	9.93	10.7	10.9	10.7
T_2- Cow urine	5.89	5.22	5.56	10.5	8.40	9.44	11.7	10.6	11.2	12.6	11.5	12.1
T_3- Vermicompost	5.58	4.80	5.19	9.3	7.93	8.60	10.7	10.3	10.5	11.4	11.0	11.2
T_4- Vermiwash	5.87	5.13	5.50	10.1	8.33	9.21	11.6	10.5	11.1	12.5	11.2	11.8
T_5- Con.bio + C.urine+ V.comp+ V.wash	5.71	5.02	5.37	9.50	8.13	8.82	11.0	10.4	10.7	11.6	11.1	11.3
T_6- Control	6.07	5.49	5.78	11.0	8.44	9.73	12.5	10.9	11.7	13.3	11.4	12.3
CD (p=0.05)	NS	0.43	0.36	0.99	0.49	0.60	1.13	NS	0.62	0.68	NS	0.57
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Among seed priming a similar trend as like plant spacing with respect to increment of no. of shoots plant^{-1} was observed during both the years 2018, 2019 and in pooled data of two years. The increase in no. of shoots plant^{-1} was continued upto harvest, but the rate of increment was more during initial stages of the crop i.e. sowing to 30 DAS followed by 30 to 60 DAS and there after 60 DAS to harvest, the rate of increment was in decreasing trend. It was also observed that more no. of shoots plant^{-1} at different periodic stages of observations at 30, 60, 90 DAS & at harvest, but the leaf size in comparison to primed treatment was small.

During the year 2018, the highest no. of shoots plant^{-1} (13.3) were recorded in control treatment (T_6) at the time of harvesting, which was significantly higher over rest of the seed primed treatments.

A similar trend during 2019 and in pooled data of two years, that the maximum no. of shoots plant^{-1} 11.4 and 12.3 respectively, were observed in T_6. It was at par with all other treatments during 2019, but in pooled data of two years which was only at par with T_2 and T_4 and significantly higher over remaining treatments.

No restriction was imposed on the growth and development of spring groundnut due to identical plant density under all plant geometries resulted equal competition for the use of basic resources. Hence, the plant spacing didn't have any significant effect on the no. of shoots produced by each plant (except during 2019).

The similar results were reported by Alam *et al* (2002), they found that when crop was sown under various geometry by keeping same plant population (20 plants m^{-2}), the area occupied for the utilization of natural resources by each plant was not affected and the plant was free from competition from other plants with respect to their growth and development. They further reported that higher no. of shoots plant^{-1} (10.57) were recorded in crop sown under 22.4 cm × 22.4 cm plant spacing over 30 cm × 16.7 cm, but the effect of planting geometry on no. of branches plant^{-1} was non-significant.

Among seed priming, due to lower plant population in T_6 followed by T_2 show reduced competition for the use of natural resources (land, nutrients, water and sunlight) resulted vigorous plant growth and produced maximum no. of shoots plant^{-1}. The effect on no. of shoots plant^{-1} was more pronounced directly by plant population but indirectly by the seed priming. The results were in accordance with the findings of Goyal *et al* (2010), they observed more no. shoots plant^{-1} (6.85) under reduced plant population (22 plants m^{-2}) in chickpea, due to luxurious crop growth compared to higher planting density (33 plants m^{-2}).

The interactional effect among seed priming and plant spacing were found to be non-significant.

4.1.4 Leaf area index (LAI)

Leaf area indicates the photosynthetic canopy of the plant, which intercepts solar radiation and produces photosynthates. The leaf area index (LAI) was observed at monthly intervals and at harvest and presented in Table 4.5. It was observed that leaf area increased continuously upto 90 DAS and later declined towards harvest of the crop.

At early growth stage (emergence to 30 DAS) the rate of canopy cover was very slow and after wards up to 90 DAS a rapid increase in LAI was observed and thereafter it decreased due to senescence of crop upto maturity. The rate of increment in LAI was to the tune of 2.04 from 30-60 DAS and 0.94 from 60- 90 DAS. The maximum LAI was found to be at 90 DAS and after wards declined in the LAI to the tune of 0.65 up to harvest (105 DAS) was observed during the year 2018, under all plant spacings.

A similar trend in increment and decrement of LAI during the year 2019 and in pooled data of two years was also observed. The increase in LAI was 2.02 and 2.03 from 30-60 DAS, 1.09 and 1.02 from 60-90 DAS and decrement in LAI from 90 DAS to harvest was to the tune of 0.57 and 0.61 respectively.

During the year 2018, the maximum LAI was observed at 90 DAS which was on an average of 3.45 and the highest LAI of 2.99 at the time of harvest of the crop was reported under G_1 plant spacing which was significantly higher than remaining two plant spacings G_2 and G_3.

A similar trend in maximum LAI of 3.11 and 3.05, during the year 2019 and in pooled data of two years, respectively were observed under same plant spacing. During the year 2019, LAI under G_1 was at par with G_2 but significantly differ from G_3 and in pooled data of two years, significantly higher over both plant spacings G_2 and G_3. The lowest LAI was observed under G_3 plant spacing during entire period crop, irrespective of the years.

Among seed priming treatments in 2018, maximum LAI was observed at 90 DAS which was on an average of 3.39. A similar trend in the maximum LAI to the tune of 3.44 at 90 DAS were observed during the year 2019 and in pooled data of two years.

The highest LAI of 3.33 at the time of harvest of the crop was observed in the consortium bio-fertilizer seed primed spring groundnut during 2018, which was significantly higher than all other seed primed treatments.

During the year 2019 and in pooled data of two years, the maximum LAI of 3.24 and 3.29 respectively, were observed under consortium bio-fertilizer seed primed crop at harvest stage. During 2019, the LAI of consortium bio-fertilizer seed primed spring groundnut was at par with T_3 treatment, but significantly higher over rest of the treatments. In pooled data of

two years the LAI was significantly higher over, all seed primed treatments. The significantly lower LAI was observed in control treatment (T_6) during the year 2018, 2019 and in pooled data of two years.

Slightly more no. of branches in G_1 plant spacing resulted higher canopy growth which intercepted more sunlight due to reduced intra-row competition and recorded significantly higher LAI (at harvest). Nesa *et al* (1989) reported significantly higher leaf area (3.08) under 45 cm × 40 cm plant spacing over other plant spacing 75 cm × 25 cm (2.61) in maize. The higher leaf area was due to reduced competition between intra-row maize plants under 45 cm × 40 cm plant spacing.

Among seed priming, the higher plant population showed increase in plant height, higher canopy cover and resulted significantly higher leaf area in consortium bio-fertilizer seed primed spring groundnut. In maize the higher leaf area (0.8 m^2) was reported by Murungu *et al* (2004), their results depict that higher germination (90%) of maize in seed primed treatment resulted higher plant stand which produced higher crop canopy and ultimately higher leaf area over non-primed maize at 45 days after emergence.

The interactional effect among seed priming and plant spacing were found to be non-significant.

4.1.5 Dry matter accumulation (g plant^{-1})

Dry matter accumulation (DMA) of spring groundnut raised with different seed primed treatments under various plant spacings was observed periodically upto harvest of the crop and results were presented in Table 4.6 and Fig 4.1. At early phase of growth, due to low temperature at night hours and slow growing habit of spring groundnut showed low rate for accumulation of biomass. As rise in the atmospheric temperature from April, a considerable increase in DMA plant^{-1} was observed in subsequent growth periods.

During initial stages of growth i.e. from 30-60 DAS under all plant spacings, slightly higher increment in DMA on an average to the tune of 22.9, 21.2 and 22.0 g plant^{-1} during the year 2018, 2019 and in pooled data of two years was observed respectively. Later a rapid increase in DMA up to 90 DAS was observed, where the increment was on an average to the tune of 37.7 g plant^{-1} during the year 2018, 2019 and in pooled data of two years respectively.

The increment in DMA continued upto harvest of the crop (105 DAS). At this stage the increment was 34.97 g plant^{-1} during 2018, 21.97 g plant^{-1} during 2019 and 28.47 g plant^{-1} in pooled data of two years under all plant spacings.

Table: 4.5 Effect of seed priming and plant spacing on periodic leaf area index (LAI) of spring groundnut

Treatment	30 DAS			60 DAS			90 DAS			At harvest		
	2018	**2019**	**Pooled**	**2018**	**2019**	**Pooled**	**2018**	**2019**	**Pooled**	**2018**	**2019**	**Pooled**
Plant spacing												
G_1- 22.5 cm × 20.0 cm	0.47	0.32	0.40	2.70	2.42	2.56	3.66	3.74	3.70	2.99	3.11	3.05
G_2- 30.0 cm × 15.0 cm	0.46	0.32	0.39	2.48	2.41	2.45	3.42	3.48	3.45	2.83	2.80	2.81
G_3- 45.0 cm × 10.0 cm	0.46	0.32	0.39	2.34	2.20	2.27	3.27	3.09	3.18	2.59	2.69	2.64
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	0.38	0.24	0.15	NS	0.28
Seed priming												
T_1- Consortium bio-fertilizer	0.52	0.34	0.43	2.86	2.51	2.69	3.89	3.72	3.81	3.33	3.24	3.29
T_2- Cow urine	0.43	0.32	0.38	2.41	2.28	2.35	3.04	3.38	3.21	2.77	2.75	2.76
T_3- Vermicompost	0.48	0.33	0.41	2.55	2.44	2.50	3.66	3.43	3.54	2.79	2.99	2.89
T_4- Vermiwash	0.44	0.30	0.37	2.49	2.31	2.17	3.32	3.32	3.32	2.91	2.82	2.86
T_5- Con.bio + C.urine+ V.comp+ V.wash	0.46	0.32	0.39	2.45	2.33	2.40	3.53	3.50	3.52	2.72	2.90	2.81
T_6- Control	0.43	0.30	0.36	2.29	2.18	2.24	2.92	3.28	3.10	2.32	2.48	2.42
CD (p=0.05)	0.04	NS	0.03	NS	NS	0.22	0.38	NS	0.25	0.38	0.32	0.26
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

During the year 2018, the maximum DMA was observed at harvesting stage of the crop under G_1 plant spacing (102.1 g plant^{-1}) which at par with other two plant spacings G_2 and G_3. A similar trend in maximum DMA at harvesting stage of the crop was noticed during the year 2019 and in mean data of two years and their respective dry matter content was 88.1 g and 95.1 g plant^{-1}.

The increment in the DMA was observed among seed priming during the year 2018 but it was at par upto 60 DAS. The increment was to the tune of 23.0 g from 30-60 DAS, 37.8 g from 60-90 DAS and 34.9 g plant^{-1} from 90 DAS to harvest of crop. A similar trend in increment of DMA was observed during the year 2019 and in pooled data of two years. The increment was to the tune of 21.2 g and 22.1 g from 30-60 DAS, 37.7 g and 37.6 g from 60- 90 DAS and 22.0 g and 28.4 g from 90 DAS to harvest of the crop respectively, which was significantly higher in treatments T_6, T_1 & T_4 than other seed primed treatment at 30 DAS, 90 DAS & at maturity except 60 DAS of the crop.

During the year 2018, the maximum DMA was observed at harvesting stage of the crop in control treatment (109.3 g plant^{-1}), which was significantly higher than other seed primed treatments. A similar trend was observed in control treatment during the year 2019 and in pooled data of two years. The respective dry matter content was 90.5 g and 99.9 g plant^{-1} and they showed significantly difference over other seed primed treatments. If so the dry matter accumulation due to better seed priming effect and hence better growth of the crop. The data showed that more the DMA in T_6, T_1 & T_4 than T_2 and T_3 treatments, which ultimately harvest more solar radiation. Thus, transfer of more photosynthates to the assimilation store house (pegs), which finally contribute more yield of the spring groundnut through more yield attributes per plant.

The uniform population density and equal availability of land, moisture and nutrients to each plant under all plant spacings resulted uniform growth and DMA. Hence, the various plant spacings had non-significant effect on dry matter accumulation of spring groundnut. Similar canopy growth and equal competition for space and nutrients among the groundnut plants were reported by Gunri *et al* (2015) under 30 cm × 10 cm (12.4 g) and 40 cm × 7.5 cm (12.1 g) dry matter plant^{-1} for those crop geometries.

Usually the seed priming would be expected to increase dry matter directly. But due to indirect effect on the crop stand, the control (T_6) treatment reported significantly higher dry matter over other seed primed treatments. The lower plant population, higher canopy growth by the use of higher space and nutrition resulted higher dry matter. The similar results were reported by Ali and Sajed (2009), they reported that significantly increased growth parameters under halo-priming in chick pea resulted higher dry matter over hydro-primed and osmo-primed crop.

The interactional effect among seed priming and plant spacing were found to be non-significant.

Table: 4.6 Effect of seed priming and plant spacing on periodic dry matter accumulation (g plant^{-1}) of spring groundnut

Treatment	30 DAS			60 DAS			90 DAS			At harvest		
	2018	**2019**	**Pooled**	**2018**	**2019**	**Pooled**	**2018**	**2019**	**Pooled**	**2018**	**2019**	**Pooled**
Plant spacing												
G_1- 22.5 cm × 20.0 cm	3.48	2.67	3.08	28.4	25.0	26.7	65.8	64.8	65.3	102.1	88.1	95.1
G_2- 30.0 cm × 15.0 cm	3.43	2.54	2.99	26.8	23.2	25.0	63.9	61.7	62.8	98.8	85.5	92.1
G_3- 45.0 cm × 10.0 cm	3.37	2.44	2.90	23.7	23.0	23.3	62.4	57.7	60.0	96.1	76.5	86.3
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	0.85	NS	NS	NS	NS
Seed priming												
T_1- Consortium bio-fertilizer	3.67	2.80	3.23	27.2	24.2	25.7	67.7	65.3	66.5	103.8	85.9	94.9
T_2- Cow urine	3.25	2.37	2.81	25.5	23.5	24.5	59.7	56.0	57.9	88.5	78.0	83.3
T_3- Vermicompost	3.63	2.77	3.20	26.0	23.7	24.8	60.7	58.2	59.4	93.2	79.7	86.4
T_4- Vermiwash	3.47	2.42	2.94	25.7	23.7	25.2	65.9	61.3	63.6	100.8	84.1	92.4
T_5- Con.bio + C.urine+ V.comp+ V.wash	3.52	2.55	3.03	25.0	24.2	24.6	61.3	59.7	60.5	98.2	82.1	90.1
T_6- Control	3.03	2.40	2.72	28.5	23.3	25.9	69.1	68.0	68.5	109.3	90.5	99.9
CD (p=0.05)	NS	0.14	0.22	NS	NS	NS	1.90	2.78	2.00	5.29	4.57	3.77
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

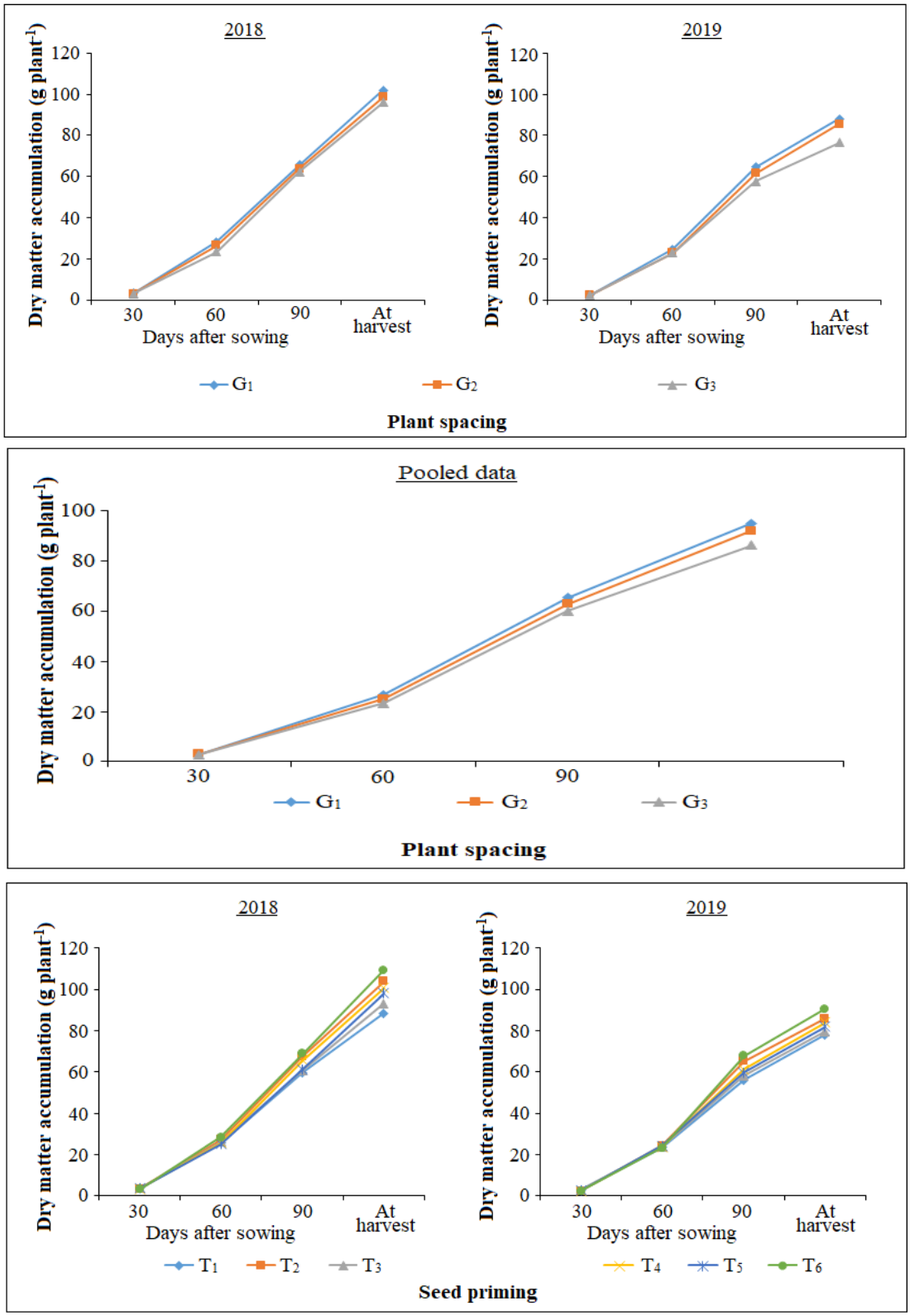

Figure 4.1 Effect of seed priming and plant spacing on dry matter accumulation (g plant^{-1}) of spring groundnut

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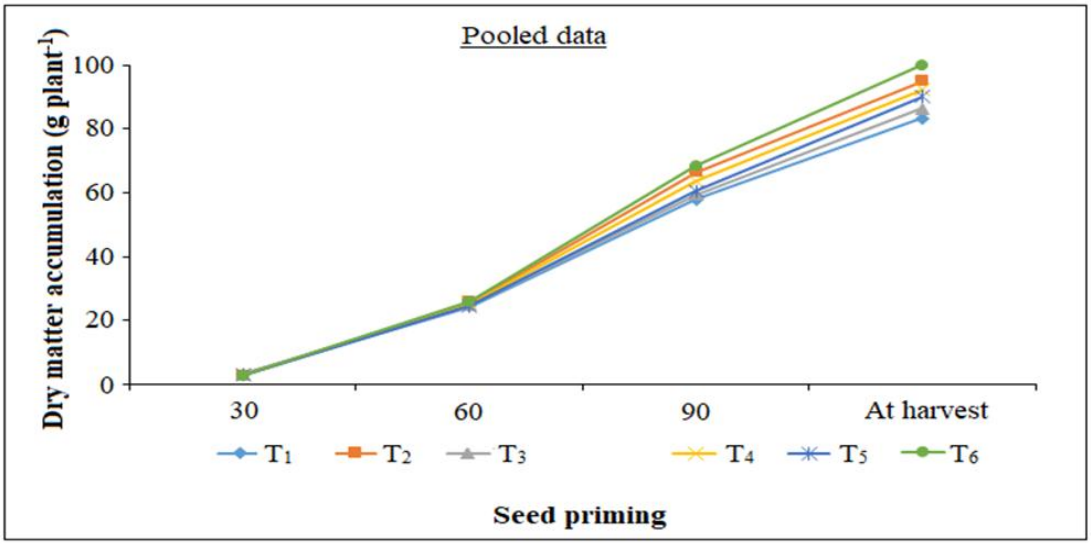
Figure 4.1 contd…



4.1.6 Days to 50% flowering

The data regarding days taken to 50% flowering was presented in Table 4.7. It revealed that during both the years 2018 and 2019 and in pooled data of two years, a non-significant difference for days to 50% flowering of spring groundnut were observed under different plant geometries and seed primed treatments. This showed that the flowering character of crop was usually governed by genetic traits of the crop and the environmental and management factors have least effect on flowering habit. The results were inclined with the results of Yasir *et al* (2018) in which they have taken different crop geometries 30 cm × 10 cm, 30 cm × 20 cm, 40 cm× 10 cm, 40 cm × 20 cm, 60 cm × 10 cm & 60 cm × 20 cm. They reported that due to genetic characters when groundnut raised under these geometries, the crop bears 50% flowering on an average of 23 days after sowing & showed non-significant effect on flowering. Chavan *et al* (2014) also reported a non-significant result due to hereditary effect on soybean seed primed with water, KCl, $CaCl_2$, potassium dihydrogen phosphate and gibberellic acid respectively, to initiate flowers on 50% plants in each treatment.

The interactional effect among seed priming and plant spacing were found to be non-significant.

4.1.7 No. of nodules plant^{-1}

The data pertaining to number of nodules plant^{-1} was presented in Table 4.7. The data revealed that during the year 2018, the maximum no. of nodules (45.0) were observed in the spring groundnut raised under G_1 plant spacing, but which was at par with rest of the plant spacings G_2 and G_3.

Table: 4.7 Effect of seed priming and plant spacing on days to 50% flowering and no. of nodules plant^{-1} of spring groundnut

Treatment	Days to 50% flowering			No. of nodules plant^{-1}		
	2018	2019	Pooled	2018	2019	Pooled
Plant spacing						
G_1- 22.5 cm × 20.0 cm	36.3	37.9	37.1	45.0	54.0	49.5
G_2- 30.0 cm × 15.0 cm	36.2	37.6	36.9	42.8	53.0	47.9
G_3- 45.0 cm × 10.0 cm	37.0	37.8	37.4	42.0	52.8	47.4
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Seed priming						
T_1- Consortium bio-fertilizer	36.0	37.6	36.8	47.7	59.1	53.4
T_2- Cow urine	34.4	38.0	36.2	41.0	51.3	46.2
T_3- Vermicompost	37.2	37.8	37.5	41.7	51.1	46.4
T_4- Vermiwash	38.1	37.7	37.9	42.6	52.0	47.3
T_5- Con.bio + C.urine+ V.comp+ V.wash	35.7	38.7	37.2	44.8	55.0	49.9
T_6- Control	37.4	37.0	37.2	41.8	51.2	46.5
CD (p=0.05)	NS	NS	NS	2.19	1.90	1.42
Interaction	NS	NS	NS	NS	NS	NS

A similar trend regarding the maximum no. of nodules i.e. 54.0 and 49.5 were observed under G_1 plant spacing during the year 2019 and in pooled data of two years respectively.

Among seed priming during the year 2018, the highest no. of nodules plant^{-1} (47.7) were observed under consortium bio-fertilizer seed primed spring groundnut, which was significantly higher over rest of the seed primed treatments.

During 2019 and in pooled data of two years, the maximum no. of nodules plant^{-1} i.e. 59.1 and 53.4 respectively, were observed under T_1 treatment and it showed significantly higher nodules compared to remaining seed primed treatments.

Groundnut is a nodule forming legume crop, due to similar canopy growth and rooting habit a non-significant difference was found among all crop geometries. The similar results were reported by Chen *et al* (1992), they reported that the maximum no. of nodules plant^{-1} (13.0) in soybean were observed under 20 cm × 12 cm plant spacing, but which was at par with other plant spacing 20 cm × 8 cm, which recorded 12.5 nodules plant^{-1}. They further

reported that due to leguminous nature of soybean crop, a non-significant effect was reported under both plant spacings.

The increased nodulation ability of consortium bio-fertilizer and its symbiotic activity (legume- *rhizobium*) in rhizosphere soil with roots of groundnut, resulted significantly higher no. of nodules in consortium bio-fertilizer seed primed crop followed by T_5 and T_4 treatments. The data further showed that there are increased nodulation in spring groundnut, further in second year (2019) when treatment was done and sown in the same experimental area. Their increment was 23.9% in consortium bio-fertilizer, 22.8% in T_5 and similarly in other treatments. Even nodulation was increased by 22.4% in control treatment also. Thus, seed priming with consortium bio-fertilizer and T_5 showed significantly increase in nodulation than other treatments. Similar trend was observed in 2019 and in pooled data of two years.

Harris *et al* (2005) reported increased nodule formation in consortium bio-fertilizer seed treated groundnut. They mentioned that higher bacterial activity in *rhizobium* inoculated crop resulted more no. of nodules plant^{-1}.

The interactional effect among seed priming and plant spacing were found to be non-significant.

4.2 Yield and yield attributes

4.2.1 No. of pegs plant^{-1}

No. of pegs plant^{-1} is one of the important yield traits and the data relating to it, is presented in Table 4.8. The data showed that during the year 2018, the maximum no. of pegs plant^{-1} (51.1) were observed under G_1 plant spacing which was significantly higher than all other spacings.

During the year 2019, the maximum no. of pegs plant^{-1} (49.3) were observed under the same plant spacing i.e. G_1. A similar trend in pooled data of two years, that highest no. of pegs plant (50.2) were found in the spring groundnut raised under G_1 plant spacing, which were significantly higher over the no. of pegs produced under G_2 and G_3 plant spacings during the year 2019 and in pooled data of two years respectively.

Among seed priming during the year 2018, the maximum no. of pegs plant^{-1} (53.2) were recorded in control treatment (T_6) which were at par with T_1, but significantly higher over rest of seed primed treatments.

A similar trend during the year 2019 and in pooled data of two years, were observed that the maximum no. of pegs plant^{-1} (52.9 and 53.0) were noticed in T_6 which was at par with T_1, but significantly higher over remaining treatments during the year 2019 and in pooled data of two years respectively.

The more no. of shoots plant^{-1} and their uniform distribution in all the directions resulted initiation of more no. of gynophores from all the shoots, which showed significantly higher no. of pegs plant^{-1} under G_1 plant spacing. These results were justified by Kathirvelan and Kalaiselvan (2007), they reported that the more no. of branches to the tune of 5.85 and high canopy growth of plant under 30 cm × 15 cm plant spacing produced significantly higher no. of pegs plant^{-1} (26.7) over 40 cm × 10 cm plant spacings in groundnut. Tana *et al* (2017) also reported that due to more no. of lateral branches in groundnut grown under 40 cm × 10 cm were recorder significantly higher no. of pegs plant^{-1} (78.8) over other plant spacings 70cm × 10 cm, 60 cm × 10 cm and 50 cm × 10.

Among seed priming lower plant population, higher individual plant canopy and more no. of shoots plant^{-1} were ultimately produced significantly higher no. of pegs plant^{-1} in control (T_6) over rest of the seed primed treatments. The results were in accordance with the findings of Sharma *et al* (2011), they confirmed that the maximum no. of pegs plant^{-1} (8.3) in groundnut were observed under control treatment, but which was at par with the *rhizobium* strain IRG-6 and significantly higher over other *rhizobium* strains IRG 40, NC-92, NRCG-22, NRC-4 and TAL-1000. They further stated that higher plant population under IRG 40, NC-92, NRCG-22, NRC-4 and TAL-1000 *rhizobium* strains treated crop resulted lower no. of shoots and ultimately showed reduced no. of pegs plant^{-1} than control.

The interactional effect among seed priming and plant spacing was found to be non-significant.

4.2.2 No. of pods plant^{-1}

The data pertaining to number of pods plant^{-1} presented in Table 4.8. It revealed that during the year 2018, the maximum no. of pods plant^{-1} (47.0) were observed under G_1 plant spacing which was significantly higher than rest of the plant spacing.

During the year 2019, the maximum no. of pods plant^{-1} (44.3) were observed under G_1 plant spacing. In pooled data of two years, 45.6 pods plant^{-1} were also found in the similar plant spacing, which were significantly higher over the no. of pods produced under G_2 and G_3 plant spacings during the year 2019 and in pooled data of two years.

Among seed priming, the maximum no. of pods plant^{-1} (46.8) were recorded in control treatment during the year 2018 which were at par with T_1 seed primed treatment, but significantly higher than the remaining treatments.

A similar trend that the maximum no. of pods plant^{-1} i.e. 48.2 and 47.5 during the year 2019 and in pooled data of two years respectively, were observed in control treatment but which was at par with T_1 and significantly higher over all other seed primed treatments.

Table: 4.8 Effect of seed priming and plant spacing on no. of pegs, pods, filled pods and pod weight of spring groundnut

Treatments	Pegs plant^{-1}			Pods plant^{-1}			Filled pods plant^{-1}			Pod weight (g plant^{-1})		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
Plant spacing												
G_1- 22.5 cm × 20.0 cm	51.1	49.3	50.2	47.0	44.3	45.6	42.2	40.4	41.3	35.3	33.0	34.2
G_2- 30.0 cm × 15.0 cm	47.8	46.4	47.1	42.7	41.4	42.1	39.5	38.5	39.0	33.9	32.6	33.2
G_3- 45.0 cm × 10.0 cm	44.9	44.0	44.4	38.8	38.9	38.9	36.0	36.1	36.0	32.3	32.4	32.3
CD (p=0.05)	3.15	2.05	2.67	2.57	2.86	1.59	2.45	3.00	1.67	2.06	NS	NS
Seed priming												
T_1- Consortium bio-fertilizer	51.5	50.0	50.7	45.7	46.5	46.1	41.6	38.5	40.1	36.1	36.9	36.5
T_2- Cow urine	43.8	45.7	44.8	38.6	37.8	38.2	33.5	33.8	33.7	28.6	28.6	28.6
T_3- Vermicompost	44.6	46.6	45.6	41.7	39.6	40.6	37.6	34.6	36.1	32.7	29.4	31.0
T_4- Vermiwash	48.0	48.8	48.4	44.1	41.0	42.6	40.1	38.0	39.0	34.8	32.1	33.4
T_5- Con.bio + C.urine+ V.comp+ V.wash	46.2	47.1	46.6	42.9	40.2	41.5	38.9	36.1	37.5	33.7	30.6	32.2
T_6- Control	53.2	52.9	53.0	46.8	48.2	47.5	42.8	40.2	41.5	37.0	38.4	37.7
CD (p=0.05)	4.70	3.43	3.81	2.79	4.68	3.41	4.01	2.91	3.43	3.20	2.86	3.97
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

The more no. of branches produced 6.6 % and 13% higher no. of pegs plant^{-1} in G_1 over G_2 and G_3, resulted higher pod formation. Jaffer and Gardner (1988) showed that the square planting geometry (0.35 × 0.30 m) produced significantly higher no. of pods than rectangular planting geometry (1.05 × 0.10 m), under identical plant density. They further reported that the square crop geometry recorded higher leaf area, dry matter and no. of shoots and finally the crop under 0.35 × 0.30 m plant geometry produced more no. of pods plant^{-1} (72), which was 60% higher than other plant geometry. Similar effect was also reported by Niru *et al* (2018) in pigeon pea.

The more no. of shoots resulted initiation of more no. of pegs plant^{-1} in control treatment (T_6). Due to lower plant population it recorded higher no. of pods plant^{-1}. The lower plant population and higher no. of pegs plant^{-1} observed by Tahir *et al* (2017) under control treatment in groundnut, which recorded significantly higher no. of pods plant^{-1} (30.5) compared to all other seed priming treatments namely 0.1% and 0.3% Fe, 0.5%and 1.0% Zn in groundnut.

The interactional effect among seed priming and plant spacing were found to be non-significant.

4.2.3 No. of filled pods plant^{-1}

The data regarding number of filled pods plant^{-1} was presented in Table 4.8. It showed that during the year 2018, the maximum no. of filled pods plant^{-1} (42.2) were observed under G_1 crop geometry which was significantly higher than the no. of filled pods observed under other two crop geometries.

During the year 2019, the maximum no. of filled pods plant^{-1} (40.4) were observed under the same crop geometry. In pooled data of two years also a similar trend that, the highest no. of filled pods plant^{-1} (41.3) were reported under G_1 crop geometry, which were significantly higher over other crop geometries (except during 2019). During the year 2019, the no. of filled pods observed under G_1 crop geometry were at par with G_2 crop geometry, but significantly higher than G_3 crop geometry.

Among seed priming, the maximum no. of filled pods plant^{-1} (42.8) were recorded in control treatment during the year 2018, which was at par with T_1 and T_4. Similar trend in no. of filled pods plant^{-1} were observed that, the maximum no. of filled pods plant^{-1} i.e. 40.2 and 41.5 were noticed in control treatment during the year 2019 and in pooled data of two years respectively, which were at par with T_1 and T_4 and significantly higher over other seed primed treatments during both the years 2018, 2019 and in pooled data of two years.

The two-year field study showed the significantly higher no. of filled pods plant^{-1} under G_1 crop geometry. It was due to production of higher plant^{-1} dry matter and its

accumulation in pods resulted proper filling of pods. Changxing *et al* (2017) were also showed the similar results, that the groundnut raised under 35 cm × 11 cm recorded higher no. of filled pods plant^{-1} (22.2), which was significantly higher and 13%, 8.3% and 34.5% higher over rest of the plant spacings 35 cm × 13 cm, 35 cm × 17 cm and 35 cm × 25 cm respectively. They further reported that higher pod number plant^{-1} resulted more no. of percent filled pods plant^{-1}.

The lower competition for natural resources among the plants due to lower plant population under control (T_6), accumulated higher dry matter in above ground canopy and its efficient translocation resulted in proper pod filling. Sajid *et al* (2011) reported similar results that, the maximum no of matured pods plant^{-1} (79.8) in control treatment may be due to more no. of leaves, shoots and pods plant^{-1} which enabled to produce more matured pods over *rhizobium* inoculated plants (56.4 matured pods plant^{-1}).

The interactional effect among seed priming and plant spacing were found to be non-significant.

4.2.4 Pod weight plant^{-1} (g)

The data pertaining to pod weight plant^{-1} was presented in Table 4.8. During the year 2018, the maximum pod weight plant^{-1} (35.3 g) was observed in the spring groundnut raised under G_1 plant spacing which was at par with G_2 (33.9 g plant^{-1}), but significantly higher than G_3.

A similar trend was observed during the year 2019 and in pooled data of two years, that the maximum pod weight i.e. 33.0 g and 34.2 g plant^{-1} respectively, were reported in G_1 plant spacing. Which were at par with G_2 and G_3 and the overall effect of plant spacing on pod weight plant^{-1} was found to be non-significant.

Among seed priming, the highest pod weight plant^{-1} (37.0 g) was observed in the control (T_6) treatment which was at par with T_1 (36.1 g) & T_4 (34.8 g), but significantly higher over rest of the seed primed treatments during the year 2018.

A similar trend during 2019 and in pooled data of two years, that the maximum pod weight of 38.4 g and 37.7 g plant^{-1} were reported in control treatment, respectively, which were at par with T_1 and significantly higher than remaining seed primed treatments.

The higher no. of pods plant^{-1} resulted decreased pod weight due to increased competition for photosynthates. Even though the maximum pod weight was recorded under G_1 plant spacing the overall effect (two-year mean) was non-significant. The similar results were confirmed by Chandrasekaran *et al* (2007), they reported that during 2003 under 45 cm × 10 cm plant spacing significantly higher pod weight plant^{-1} was observed, but during 2004 the effect was at par with other plant spacings 30 cm × 10 cm and 30 cm × 15 cm. They

further reported that due to higher no. of pods plant^{-1} (19.9 g) under 45 cm × 10 cm plant spacing the pod weight plant^{-1} (38.9 g), was high but the competition for photosynthates resulted in reduced individual pod weight and showed a non-significant effect.

Among seed priming under control treatment, the higher no. of filled pods due to high dry matter production and its translocation to pods and resulted higher pod weight plant^{-1} in control. Murungu *et al* (2004) confirmed the similar results that, the low plant population produced high dry matter in un-primed maize produced maximum no. of grains cob^{-1} (396), which resulted higher grain weight (41 g plant^{-1}) over hydro-primed maize.

The interactional effect among seed priming and plant spacing on pegs plant^{-1}, pods plant^{-1}, filled pods plant^{-1} and pod weight plant^{-1} were found to be non-significant.

4.2.5 No. of kernels pod^{-1}

The data concerning to number of kernels pod^{-1} was presented in table 4.9. During both the years (2018 and 2019) and in pooled data of two years, the maximum no. of kernels pod^{-1} were found under G_1 plant spacing, but which was at par with other plant spacings. The G_1 plant spacing showed an increment of 2.2%, 2.3% and 2.2% higher no. of kernels over G_3, during the year 2018, 2019 and in pooled data of two years respectively but the increment over G_2 was negligible.

A similar trend was reported in seed primed treatments, that the maximum no. of kernels 2.37, 2.23 and 2.30 pod^{-1} were observed under Consortium bio-fertilizerseed primed treatment, but which was at par with rest of the seed primed treatments during the year 2018, 2019 and in pooled data of two years respectively.

The spring groundnut variety TG 37A bears 1-3 seeds pod^{-1} and usually 2, was common. This character of variety was usually governed by the genetic traits and in some cases environment and management factors. The identical crop area under all plant spacings provides similar environment for development of pods and seeds in each pod. Hence, the no. of kernels pod^{-1} was not affected. The similar dominance of genetic character was observed in groundnut variety R 2001-3 by Gunri *et al* (2015), they found a non-significant difference in the no. of kernels pod^{-1} (2.1) under 30 x 10 cm and 40 x 7.5 cm plant geometry, due to varietal character.

Among seed priming solubility and availability of N in consortium bio-fertilizer seed primed rhizosphere soil produced more no. of seeds pod^{-1}, but due to varietal effect it was non-significant. The results were in accordance with Singh *et al* (2011), who reported a non-significant difference among *rhizobium* treated and un-treated crop. The *rhizobium* treated crop contain more no. of kernels pod^{-1} (1.61) this was due genetic character of ICGS-76 variety.

The interactional effect among seed priming and plant spacing were found to be non-significant.

4.2.6 100 kernel weight (g)

The data pertaining to 100 kernel weight (test weight) was presented in table 4.9. During both the years 2018, 2019 and in pooled data of two years, the highest test weight was found in the spring groundnut raised under G_3 plant spacing, which was at par with rest of the plant spacings. The G_3 plant spacing showed an increment of 4%, 3.6% and 3.7% higher kernel weight over G_1 but the increment over G_2 was negligible during the year 2018, 2019 and in pooled data of two years respectively.

A similar trend was observed in seed priming that, the highest test weight of 48.6 g, 51.7 g and 50.2 g were observed under consortium bio-fertilizer seed primed treatment during the year 2018, 2019 and in pooled data of two years respectively, but which were at par with all other seed primed treatments.

The groundnut was deep rooted crop and the same under all plant spacing resulted no special effect on the nutrient absorption of plant. Due lower no. of pods plant^{-1} and high plant nutrition under G_3 plant spacing resulted higher 100 kernel weight, but not significant. Gunri *et al* (2015) reported that, due to no severe competition for the uptake of nutrients under 30 x 10 cm and 40 x 7.5 cm plant spacing resulted equal nutrient absorption and its conversion and accumulation resulted a non-significant difference in 100 kernel weight of groundnut.

The higher plant population in consortium bio-fertilizer seed primed spring groundnut showed lower no. of yield attributes and lower no. of pods also. Due to reduction in pod number, the competition for nutrients among pods was not appeared. The solubility and availability of high N and lower no. of pods plant^{-1} under consortium bio-fertilizer primed crop resulted higher kernels weight. The similar results were reported by Yari *et al* (2011), they reported that the reduced no. of kernels spike^{-1} (27.1) in wheat seed primed with KCl (2%) reported higher 1000 kernel weight (48.0 g), which was 2.7% higher over control, even though the control recorded higher no. of kernels spike^{-1} (27.6), but the kernel weight was at par with each other. Hafeez *et al* (2011) also reported a non-significance difference between control and hydro-primed treatment in rice. They reported 58% higher 1000 seed weight (16.6 g) in hydro primed treatment over control, even though it recorded lower no. of kernels panicle^{-1} (67.8) in rice. Which was 58.1% higher over control even though the control recorded significantly higher no. of kernels panicle^{-1} (81.4).

The interactional effect among seed priming and plant spacing were found to be non-significant.

4.2.7 Shelling percentage (%)

The data pertaining to shelling percentage was presented in Table 4.9. During the year 2018, the highest shelling percentage (64.3 %) was observed in the spring groundnut grown under G_1 crop geometry which was at par with other crop geometries G_2 and G_3.

A significance difference was found during the year 2019 and in pooled data of two years. The higher shelling percentage 63.8 % and 62.7% were reported under G_1 and G_2 crop geometries respectively during 2019, but which were at par with each other. The only G_1 crop geometry was significantly higher over G_3 and it recorded 3.6 % more shelling percent over G_3.

In pooled data of two years, the higher shelling percentage of 64.1% and 63.3% were reported in G_1 and G_2 crop geometry respectively, but which were at par with each other, plant spacing G_1 was significantly higher shelling percentage over G_3. It was 3.4% higher over G_3 crop geometry.

Among seed priming during the year 2018, 2019 and in pooled data of two years the highest shelling percentage 64.3, 63.0 and 63.7% respectively, were observed under consortium bio-fertilizer primed seed of spring groundnut but which were at par with rest of the seed primed treatments.

The reduced intra-row competition in G_1 plant spacing produced more LAI, plant dry matter and more no. of kernels pod^{-1}. Even under lowered kernel weight due to more no. of kernels pod^{-1}, G_1 reported significantly higher shelling percentage. The lower competition for space, light and nutrition under 30 cm×10 cm plant spacing in groundnut were reported by Meena *et al* (2011). They further reported that, due to these results the higher shelling percentage (65.5%) was reported under 30 cm×10 cm plant spacing which was significantly higher over other plant spacings 22.5 cm × 10 cm and 22.5 cm × 8 cm.

All seed primed treatments showed a non-significant difference with regard to shelling percentage, even though higher numerical was recorded in T_1. It was due to nearly equal no. of seeds pod^{-1} and their similar seed weight under all treatments. Elgailani *et al* (2015), reported similar results that, equal no. of pods (42.8 and 42.0) and similar kernel weight (32.2 and 31.8 g per 100 seed) under primed and non-primed groundnut respectively, showed a non-significant difference in shelling percentage. They further reported that both primed and non-primed treatments recorded 67.1 and 66.8 shelling percentage, respectively, but at par with each other due to nearly similar seed weight.

The interactional effect among seed priming and plant spacing were found to be non-significant.

Table: 4.9 Effect of seed priming and plant spacing no. of kernels, 100 kernel weight and shelling percentage of spring groundnut

Treatment	No. of kernels pod^{-1}			100 kernel weight (g)			Shelling percentage (%)		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
Plant spacing									
G_1- 22.5 cm × 20.0 cm	2.37	2.23	2.30	47.0	49.7	48.4	64.3	63.8	64.1
G_2- 30.0 cm × 15.0 cm	2.36	2.22	2.29	48.5	50.1	49.3	63.8	62.7	63.3
G_3- 45.0 cm × 10.0 cm	2.32	2.18	2.25	48.9	51.5	50.2	62.3	61.6	62.0
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	1.16	1.43
Seed priming									
T_1- Consortium bio-fertilizer	2.37	2.23	2.30	48.6	51.7	50.2	64.3	63.0	63.7
T_2- Cow urine	2.34	2.20	2.27	47.6	48.4	48.0	62.7	62.3	62.5
T_3- Vermicompost	2.36	2.22	2.29	47.6	51.5	49.6	63.9	62.3	63.1
T_4- Vermiwash	2.35	2.21	2.28	47.9	50.6	49.3	63.4	62.3	62.9
T_5- Con.bio + C.urine+ V.comp+ V.wash	2.35	2.21	2.28	47.4	51.4	49.4	63.8	62.1	63.0
T_6- Control	2.32	2.18	2.25	46.3	47.1	46.7	62.4	61.4	61.9
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.2.8 Pod yield (q ha^{-1})

The pod yield is a standard criterion to identify the efficacy of various treatments in present situation. The data pertaining to pod yield of spring groundnut was presented in Table 4.10.

During the year 2018, the pod yield under G_1 and G_2 plant spacing were to the tune of 45.5 and 43. 3 q ha^{-1} respectively. During the year 2019, the maximum pod yield of 48.9 q ha^{-1} and 45.6 q ha^{-1} were also reported under G_1 and G_2 plant spacings respectively, but which were at par with each other and significantly higher over the pod yield observed under G_3 plant spacing during the year 2018 and 2019.

In pooled data of two years, the maximum pod yield (47.2 q ha^{-1}) was observed under G_1 plant spacing which was significantly higher over the pod yield observed under the remaining plant spacings.

Among seed priming, the maximum pod yield (49.5 q ha^{-1}) was observed in consortium bio-fertilizer seed primed spring groundnut during the year 2018, which was significantly higher over rest of the seed primed treatments.

During the year 2019, the pod yield of 49.7 q ha^{-1} and 47.7 q ha^{-1} were observed in consortium bio-fertilizer(T_1) and vermicompost (T_3) seed primed treatments respectively, which were at par with each other but significantly higher than all other seed primed treatments.

The pooled data of two years, the maximum pod yield of 49.6 q ha^{-1} was observed under consortium bio-fertilizer seed primed treatment which was significantly higher over all other seed primed treatments in pooled data of two years.

The more no. of shoots $plant^{-1}$ produced significantly higher yield attributes such as no. of pegs, pods and filled pods $plant^{-1}$ under G_1 plant spacing which would result significantly higher pod yield. The findings of Gunri *et al* (2015), showed that the crop grown under 30 cm × 10 cm plant spacing produced 4% higher no. of pods $plant^{-1}$, which resulted in 3% higher yield over 40 cm × 7.5 cm. Arif *et al* (2016) also confirmed that the groundnut raised under normal sowing 30 cm × 10 cm in 90 cm drip line was recorded 15.7 % higher no. of pods $plant^{-1}$ and 9% higher pod yield over the crop grown under same plant spacing in 120 cm drip line, paired row sowing in 90 cm and 120cm drip line respectively.

However, almost all yield attributes were lower under consortium bio-fertilizer seed primed crop than control (T_6), but due higher plant population i.e. 2,06,000, 2,02,000 and 2,04,000 during the year 2018, 2019 and in pooled data of two years respectively, the consortium bio-fertilizer seed primed crop recorded significantly higher pod yield. The

similar results were reported by Sajid *et al* (2011), they reported that the inoculation of *rhizobia* recorded significantly higher pod yield (1.9 q ha^{-1}) to the tune of 33% over un-inoculated groundnut crop. They further reported that the higher plant population under *rhizobium* crop to the tune of 16% over the un-inoculated treatment, resulted higher pod yield. The similar results in *rhizobium* groundnut crop over control was also reported by Ahmad *et al* (2009).

The interactional effect among seed priming and plant spacing were found to be non-significant

4.2.10 Haulm yield (q ha^{-1})

The data pertaining to haulm yield of spring groundnut was presented in Table 4.10, showed that during the year 2018, the maximum haulm yield (106.2 q ha^{-1}) was observed in the spring groundnut grown under G_1 crop geometry. Similarly, during 2019 and in pooled data of two years, the maximum haulm yield of 111.7 q ha^{-1} and 108.9 q ha^{-1} respectively, were reported under same crop geometry, which were significantly higher over other crop geometries G_2 and G_3 during the year 2018, 2019 and in pooled data of two years.

Among seed priming, the highest haulm yield (113.8 q ha^{-1}) was observed in consortium bio-fertilizer seed primed spring groundnut crop during 2018. A similar trend was observed during the year 2019 and in pooled data of two years, showed that the maximum haulm yield of 107.9 q ha^{-1} and 110.9 q ha^{-1} were respectively, observed under consortium bio-fertilizer seed primed crop. Haulm yield under consortium bio-fertilizer was significantly higher over rest of the treatments except during 2019. During the year 2019 the yield under consortium bio-fertilizer treatment was at par with vermicompost (T_3) and con.bio + c.urine+ v.comp+ v.wash (T_5) seed primed treatments, but all these treatments were significantly higher over rest of the seed primed treatments.

The higher plant canopy, uniform plant growth under reduced intra-row competition in G_1 crop geometry produced significantly higher haulm yield. The similar results were reported by Arif *et al* (2016), they confirmed that significantly higher haulm yield (5.4 q ha^{-1}) of groundnut under 30 cm × 10 cm in 90 cm drip line crop geometry over the crop grown under same plant spacing in 120 cm drip line, paired row sowing in 90 cm and 120cm drip line respectively, was due to higher leaf area to the tune of 23% which contributed 9% higher haulm yield.

Among seed priming due to higher population and increased plant growth under consortium bio-fertilizer seed primed crop recorded 29% higher haulm yield over control treatment. Similarly, Elgailani *et al* (2015) reported that higher plant stands of 16, 23, 16.1 and 55.8% under seed primed sorghum (7.7 q), cow pea (8.3 q), groundnut (3.1 q) and

sesame (19 q ha^{-1}) respectively, reported significantly higher straw yield compared to non-primed plants in above crops.

The interactional effect among seed priming and plant spacing were found to be non-significant.

4.2.10 Biological yield (q ha^{-1})

The data pertaining to biological yield of spring groundnut was presented in Table 4.10. During 2018, the maximum biological yield (151.7 q ha^{-1}) was observed under G_1 plant spacing which was significantly higher over remaining plant spacings.

The maximum biological yield of 165.5 q ha^{-1} and 158.6 q ha^{-1} were reported in G_1 plant spacing during the year 2019 and in pooled data of two years respectively, which were significantly higher over the biological yield recorded under G_2 and G_3 plant spacings.

Among seed priming the highest biological yield (163.3 q ha^{-1}) was observed under consortium bio-fertilizer seed primed spring groundnut during the year 2018, which was significantly higher than the rest of the seed primed treatments.

During the year 2019, the biological yield of 157.5 q ha^{-1}, 153.8 q ha^{-1} and 149.6 q ha^{-1} were reported in consortium bio-fertilizer (T_1), vermicompost (T_2) and con.bio + c.urine+ v.comp+ v.wash (T_5) seed primed treatments respectively, which were at par with each other but only consortium bio-fertilizer and vermicompost treatments were significantly superior over rest of the seed primed treatments T_2, T_4 and T_6. The con.bio + c.urine+ v.comp+ v.wash (T_5) was at par with T_4 and significantly differ from T_2 and T_6.

In pooled data of two years, the significantly higher biological yield (160.4 q ha^{-1}) under consortium bio-fertilizer seed treatment over all other seed primed treatments of spring groundnut.

Under two-year study it concluded that due to 6.3 % and 24% higher pod yield and 10% and 23.2% higher haulm yield in G_1 plant spacing over other two plant spacings G_2 and G_3 respectively, reported significantly higher biological yield. The biological yield I G_1 was to the tune of 13.6% and 27% higher over plant spacings G_2 and G_3 respectively. The similar results were reported by Meena *et al* (2011), they concluded that significantly higher biological yield (5.3 q ha^{-1}) was produced by the crop planted under 22.5 cm × 8.0 cm spacing, which was due to higher pod yield (5%) and haulm yield (36%) over other two plant spacings in 30.0 cm × 10.0 cm and in 22.5 cm × 10.0 cm.

Table: 4.10 Effect of seed priming and plant spacing on pod yield, haulm yield, biological yield and harvest index (HI) of spring groundnut

Treatment	Pod yield (q ha^{-1})			Haulm yield (q ha^{-1})			Biological yield (q ha^{-1})			HI		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
Plant spacing												
G_1- 22.5 cm × 20.0 cm	45.5	48.9	47.2	106.2	111.7	108.9	151.7	165.5	158.6	0.30	0.33	0.31
G_2- 30.0 cm × 15.0 cm	43.3	45.6	44.4	91.2	100.7	99.0	134.5	144.7	139.6	0.33	0.30	0.31
G_3- 45.0 cm × 10.0 cm	35.8	40.6	38.2	88.4	88.4	88.4	124.2	125.6	124.9	0.29	0.30	0.29
CD (p=0.05)	2.45	4.76	1.60	4.95	5.26	4.34	5.49	8.87	5.70	0.01	0.02	0.01
Seed priming												
T_1- Consortium bio-fertilizer	49.5	49.7	49.6	113.8	107.9	110.9	163.3	157.5	160.4	0.29	0.31	0.30
T_2- Cow urine	38.7	41.7	40.2	85.8	94.6	90.2	124.5	136.2	130.4	0.31	0.30	0.31
T_3- Vermicompost	42.1	47.2	44.7	100.4	106.6	103.5	142.6	153.8	148.2	0.30	0.31	0.30
T_4- Vermiwash	40.7	45.8	43.3	89.1	97.7	93.4	129.8	143.5	136.7	0.31	0.32	0.32
T_5- Con.bio + C.urine+ V.comp+ V.wash	41.3	46.1	43.7	91.5	103.5	97.5	132.7	149.6	141.2	0.31	0.31	0.31
T_6- Control	36.8	39.6	38.1	80.9	91.3	86.1	117.7	130.9	124.3	0.31	0.30	0.31
CD (p=0.05)	4.16	3.20	3.64	12.4	8.93	6.93	14.1	8.30	7.69	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Among seed priming, the higher plant population in T_1 resulted increased plant height, LAI and significantly higher pod and haulm yield and it recorded significantly higher biological yield. The results were in accordance with the findings of Tahir *et al* (2017), they reported that the higher plant height (22.6%) and pod yield (20%) in groundnut seed primed with 0.3% Fe × 1.0% Zn recorded significantly higher (18.8%) biological yield over control treatment.

The interactional effect among seed priming and plant spacing were found to be non-significant.

4.2.11 Harvest index

The data pertaining to harvesting index was presented in table 4.10. During the year 2018, the maximum harvest index to the tune of 0.33 was found under G_2 crop geometry, which was significantly higher over other two crop geometries G_1 and G_3.

But during the year 2019, the significantly higher harvest index (0.33) was found in crop geometry G_1. In pooled data of two years, highest harvest index to the tune of 0.31 was found under G_1 and G_2 crop geometries, which were significantly higher over G_3 crop geometry.

Among seed priming during the year 2018, the highest harvest index to the tune of 0.31 was observed under T_2, T_4, T_5 and T_6, but all the seed primed treatments in regarding with harvest index were at par with each other.

During the year 2019 and in pooled data of two years, the maximum harvest index (0.32) was observed under vermiwash (T_4) seed primed treatment, but a non-significant difference was found among all seed priming treatments.

The harvest index was not an efficient method to judge higher crop yield but it indicates efficient translocation of photosynthates from source to sink. During both the years 2018, 2019 and in pooled data of two years, the lowest HI were reported under G_3 crop geometry. The narrow intra-row spacing in G_3 crop geometry showed increased competition among plants and resulted the lower HI. The similar results were reported by Meena *et al* (2011), they showed that the lowest HI (0.30) in groundnut raised under 22.5 cm × 8.0 cm crop geometry compared to other two crop geometries 30.0 cm × 15.0 cm and 22.5 cm × 10.0 cm. they further reported that increase competition among plants under narrow crop spacing resulted lower HI.

The all seed priming treatments were equally important in efficient partitioning of dry matter in to economic yield. Hence, during both the years 2018, 2019 and in pooled data of two years, non-significant difference was observed among all seed primed treatments. But

the trend was in favour of vermicompost (T_3) treatment. The similar results were reported by Rahul and Sachin (2015), they showed that the maximum harvest index (0.41) was found in soybean seed primed by hydration with 100 ppm GA_3 for 12 hrs, but which was at par with all other seed primed treatments hydration with distilled water, 2% $CaCl_2$, 0.5% KNO_3, 80ppm IAA, hydration with water for 12hrs + 3g Bavistin and control. They further reported that harvest index was the ratio of partitioning of biological yield into economic yield and it was not affected by any seed priming treatments.

The interactional effect among seed priming and plant spacing were found to be non-significant.

4.3 Quality analysis

The data pertaining to oil and protein content of spring groundnut were presented in Table 4.11.

4.3.1 Oil content (%)

Oil content in kernels is one of the important character which influences the quality of seeds. During crop season (2018), the oil content of the crop raised under G_1 plant spacing was to the tune of 49.7%, which was at par with other crop geometries G_2 and G_3. During the year 2019, the higher oil content (49.6%) in groundnut kernel was found in the spring groundnut grown under G_1 plant spacing, the highest oil content (49.7%) in pooled data of two years was also found in G_1 plant spacing, which was at par with remaining two plant geometries (G_2 and G_3) during the year 2019 and in pooled data of two years.

Among seed priming during the year 2018, the higher oil content (49.7%) was found in consortium bio-fertilizer seed primed spring groundnut, which was at par with other seed primed treatments. A similar trend of more oil content of spring groundnut kernels was found in consortium bio-fertilizer seed primed treatment during the year 2019 and in pooled data of two years and their respective oil content was 49.6% and 49.7%, but which were at par with rest of the seed primed treatments.

Usually the oil content was varied with genotypes, stress effect on growth and maturity of the crop. Thus, it showed that all seed priming treatments and plant spacings were equally important for the oil content of spring groundnut and which was well depicted to through a non-significance difference in oil content among all seed primed treatments and plant spacings. But the trend was on G_1 (49.7%) plant spacing and among seed priming with consortium bio-fertilizer side (49.6%) was more than other treatments.

The similar varietal and environmental effect on oil content of groundnut were reported by Hussain *et al* (2002), they showed a non-significant effect among all plant

densities 10000, 20000 and 40000 plants ha^{-1}, even though the maximum oil content (49.6%) was recorded in 10000 plant density ha^{-1}.

The similar results were reported by Das and Mohanty (2018), they observed that the maximum oil content (44.8%) was found in moist sand conditioning for 24 h (MSC-24 h) treatment in groundnut, but which was at par with all other seed primed treatments MSC for 36, 48, 60 and 72 hrs and hydro-priming for 2,3,4 and 5 hrs. Subbaraman and Selvaraj (1989) also reported that soaking of groundnut seeds in 0.50% $CaCl_2$ solution for 32 h followed by 10 h drying resulted in higher oil content (50.72%), compared to that in water soaking (47.19%).

The interactional effect among seed priming and plant spacing were found to be non-significant.

4.3.2 Protein content (%)

Protein content (Table 4.11) in groundnut kernel is one of the important character which impacts the quality of seeds.

During the year 2018, the protein content of the crop raised under G_1, G_2 and G_3 plant spacing was to the tune of 26.5%, 26.4% and 26.3% respectively, which were at par with each other. During the year 2019, the higher protein content (26.1%) was found in the spring groundnut grown under G_1 plant spacing, the highest protein content (26.3%) in pooled data of two years was also found in G_1 plant spacing, but the protein content of 2019 and in pooled data of two years were at par with protein content of remaining two plant geometries G_2 and G_3.

Among seed priming during the year 2018, the higher protein content (26.5%) was found in consortium bio-fertilizer seed primed spring groundnut, which was at par with other seed primed treatments. A similar trend in highest protein content of spring groundnut kernels was found in consortium bio-fertilizer seed primed treatment during the year 2019 and in pooled data of two years and their respective protein content was 26.1% and 26.3%, but which were at par with remaining seed primed treatments.

Usually the protein content was varied with genotypes, stress effect on growth and maturity of the crop. Thus, it showed that all seed priming treatments and plant spacings were equally important for the protein content of spring groundnut and which was well depicted to through a non-significance difference in protein content among all seed primed treatments and plant spacings. But the trend was on G_1 (26.3%) plant spacing and among seed priming consortium bio-fertilizer seed primed side (26.3%) but at par with other treatments.

The similar varietal and environmental effect on protein content of groundnut were reported by Hussain *et al* (2002), they showed a non-significant effect among different plant

densities varied from10000, 20000 and 40000 plants ha^{-1} respectively, even though the maximum protein content (25.5%) was recorded in 10000 plant density ha^{-1}.

The similar results were reported by Das and Mohanty (2018), they showed that the maximum protein content (26.7%) was found in moist sand conditioning for 24 h (MSC-24 h) treatment in groundnut, but which was at par with all other seed primed treatments MSC for 36, 48, 60 and 72 hrs and hydro-priming for 2,3,4 and 5 hrs.

The interactional effect among seed priming and plant spacing were found to be non-significant.

Table: 4.11 Effect of seed priming and plant spacing on oil content and protein content of spring groundnut

Treatment	Oil content (%)			Protein content (%)		
	2018	2019	Pooled	2018	2019	Pooled
Plant spacing						
G_1- 22.5 cm × 20.0 cm	49.7	49.6	49.7	26.5	26.1	26.3
G_2- 30.0 cm × 15.0 cm	49.6	49.4	49.5	26.4	26.0	26.2
G_3- 45.0 cm × 10.0 cm	49.5	49.4	49.4	26.3	25.9	26.1
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Seed priming						
T_1- Consortium bio-fertilizer	49.7	49.6	49.6	26.5	26.1	26.3
T_2- Cow urine	49.5	49.4	49.5	26.3	25.9	26.1
T_3- Vermicompost	49.7	49.5	49.6	26.4	26.0	26.2
T_4- Vermiwash	49.5	49.4	49.4	26.4	26.0	26.2
T_5- Con.bio + C.urine+ V.comp+ V.wash	49.7	49.6	49.6	26.5	26.1	26.3
T_6- Control	49.5	49.3	49.4	26.2	25.8	26.0
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS

4.4 Economics

The data pertaining to gross returns, net returns and B:C ratio (Table 4.12) and gross returns and net returns of spring groundnut represented in Fig 4.2, has been discussed one by one in context to plant spacing and seed priming.

4.4.1 Gross returns (₹ ha^{-1})

During the year 2018, the highest gross return (gross income) of Rs.137500 was obtained by the spring groundnut raised under G_1 plant spacing which was to tune of 5.93% and 31.3% higher over remaining plant spacings G_2 and G_3 respectively. The gross income obtained in G_1 plant spacing was at par with G_2, but significantly higher over G_3 plant spacing.

During the year 2019 and in pooled data of two years, the maximum gross income of Rs.149500 and Rs.143500 ha^{-1} were observed under G_1 plant spacing respectively. The gross income was 14.9%, 38.9% and 10.5%, 35.1% higher over G_2 and G_3 plant spacings during the year 2019 and in pooled data of two years respectively, and which was significantly higher over rest of the plant spacings.

Among seed priming the maximum gross income Rs.136100 was observed under consortium bio-fertilizer seed primed spring groundnut during the year 2018, but which was at par with other treatments T_3 (Rs.126200), T_4 (Rs.121300) and T_5 (Rs.123200) and T_1, T_3 and T_5 were significantly higher over remaining seed primed treatments T_2 and T_6, but T_4 was at par with them .

A similar trend in gross income was found during the year 2019 that, the maximum gross return Rs.149400 was observed under consortium bio-fertilizer seed primed spring ground nut, but which was at par with other treatments T_3, T_4 and T_5 and only T_1, T_3 and T_5 were significantly over remaining treatments T_2 and T_6 and but T_4 was at par with them.

In pooled data of two years, the gross income of Rs.142700 and Rs.133600 were observed under consortium bio-fertilizer and vermicompost seed primed treatments respectively, which were at par with each other, but only consortium bio-fertilizer treatment was significantly higher over rest of the seed primed treatments.

Under two-year study the spring groundnut grown under G_1 plant spacing reported 6.3% and 23.6% higher pod yield and 10% and 23% higher haulm yield over G_2 and G_3 respectively. Due to higher yield under G_1 plant spacing recorded significantly higher gross income. Yasir *et al* (2018), confirmed that the higher pod yield (2.1 q ha^{-1}) and haulm yield (2.6 q ha^{-1}) under 30 cm × 20 cm resulted significantly higher gross return (Rs. 20451) over 30 cm × 15 cm, 40 cm × 15 cm, 40 cm × 20 cm, 60 cm × 15 cm and 60 cm × 20 cm plant spacing. They further reported that the crop under 30 cm × 20 cm showed 13.5, 19.3, 38.7, 79.7 and 62.6% higher gross income over above mentioned plant spacings respectively.

Similarly, due to higher pod yield on an average of two years 49.6 q ha^{-1} and haulm yield 110.9 q ha^{-1} under consortium bio-fertilizer primed crop, it recorded highest gross

income. The results were in accordance with the findings of Binag *et al* (2012), they reported that significantly higher gross returns of Rs. 170613 ha^{-1} was given by the rice crop, when the crop raised by alternate hydro-primed and dried before sowing. They further reported that the higher gross return rice crop was mainly due its 62.1% higher grain yield under alternate hydro-priming and drying treatment over control.

The interactional effect among seed priming and plant spacing were found to be non-significant.

4.4.2 Net returns (₹ ha^{-1})

During the year 2018, the maximum net return of Rs.93300 ha^{-1} was obtained by the spring groundnut raised under G_1 plant spacing which was to tune of 8.36% and 54% higher over remaining plant spacings G_2 and G_3 respectively. The net return obtained by G_1 plant spacing was at par with G_2, but significantly higher over G_3 plant spacing.

The highest net return of Rs.96300 and Rs.94800 were observed under G_1 plant spacing during the year 2019 and in pooled data of two years respectively. The observed net return was 25.1%, 77.0% and 16.3%, 64.9% higher over G_2 and G_3 plant spacings during the year 2019 and in pooled data of two years respectively and significantly resulted higher net returns than other plant spacings.

Among seed priming during the year 2018, the maximum net returns Rs.92400 was observed under consortium bio-fertilizer seed primed spring groundnut. A similar trend in net returns was found during the year 2019 and in pooled data of two years, that the maximum net return of Rs.96900 and Rs.94700 were observed under consortium bio-fertilizer seed primed spring groundnut respectively, which were significantly higher over rest of the seed primed treatments during both the years 2018, 2019 and in pooled data of two years.

The higher pod and haulm yield of spring groundnut under G_1 plant spacing reported higher gross returns, but the cost of cultivation under all plant spacings was almost similar therefore G_1 resulted higher net returns over G_2 and G_3. Arif *et al* (2016) also confirmed the similar results that, the groundnut grown 30 cm × 10 cm in 90 cm drip line crop geometry given net returns of Rs. 85658 ha^{-1}, which was significantly 37.1% and 17.1% higher over the crop grown under same plant spacing in 120 cm drip line and paired row sowing in 90 cm respectively, but at par with paired row sowing in 120cm drip line but showed only 4.6% higher net returns over it. They further reported that the higher net returns were mainly due to higher pod and haulm yield under 30 cm × 10 cm in 90 cm drip line plant spacing.

Table: 4.12 Effect of seed priming and plant spacing on gross returns, net returns and benefit cost ratio (B:C) of spring groundnut

Treatment	Gross returns ($\times 10^3$ ₹ ha^{-1})			Net returns ($\times 10^3$ ₹ ha^{-1})			B:C ratio		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
Plant spacing									
G_1- 22.5 cm × 20.0 cm	137.5	149.5	143.5	93.3	96.3	94.8	3.11	2.81	2.95
G_2- 30.0 cm × 15.0 cm	129.8	130.1	129.9	86.1	77.0	81.5	2.97	2.45	2.68
G_3- 45.0 cm × 10.0 cm	104.7	107.6	106.2	60.6	54.4	57.5	2.37	2.02	2.18
CD (p=0.05)	8.20	17.3	5.50	7.40	12.4	6.40	0.13	0.33	0.10
Seed priming									
T_1- Consortium bio-fertilizer	136.1	149.4	142.7	92.4	96.9	94.7	3.11	2.85	2.97
T_2- Cow urine	114.7	122.5	118.6	71.5	70.6	71.0	2.66	2.36	2.49
T_3- Vermicompost	126.2	141.1	133.6	82.2	88.1	85.1	2.87	2.66	2.75
T_4- Vermiwash	121.3	136.5	128.9	76.3	82.5	79.4	2.70	2.53	2.60
T_5- Con.bio + C.urine+ V.comp+ V.wash	123.2	137.3	130.2	76.6	81.8	79.2	2.64	2.47	2.55
T_6- Control	108.0	114.6	111.3	64.9	63.5	64.2	2.51	2.24	2.36
CD (p=0.05)	14.0	15.3	10.6	9.40	8.60	6.70	0.26	0.29	0.20
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS

Similarly, higher net returns in consortium bio-fertilizer seed primed crop was also due to significantly higher pod and haulm yield which would result higher net returns. Lower yield and least gross returns in control which ultimately resulted least net returns among all seed primed treatments. The similar results were reported by Abdelrahman and Jens (2011), reported that due to higher crop yield in hydro-primed crop of groundnut and cowpea were given significantly higher net returns of Rs. 19205 and Rs. 12955 respectively, over non-primed treatments.

The interactional effect among seed priming and plant spacing were found to be non-significant.

4.4.3 B:C ratio (BCR)

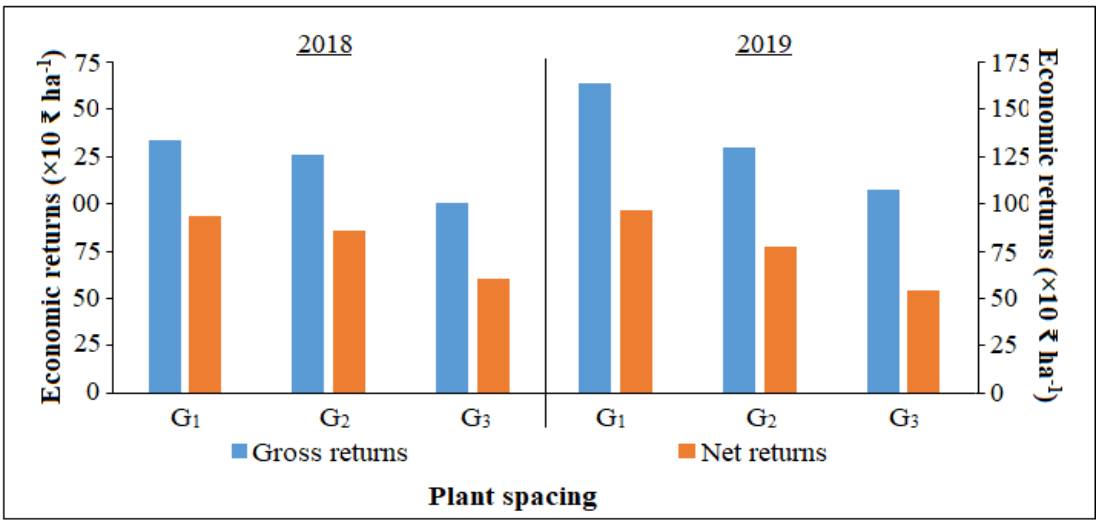
During the year 2018, the maximum BCR of 3.11 was observed under G_1 plant spacing which was to tune of 4.71% and 31.2% higher over remaining plant spacings G_2 and G_3 respectively. The BCR observed in G_1 plant spacing was at par with G_2, but both G_1 and G_2 were significantly higher over G_3 plant spacing.

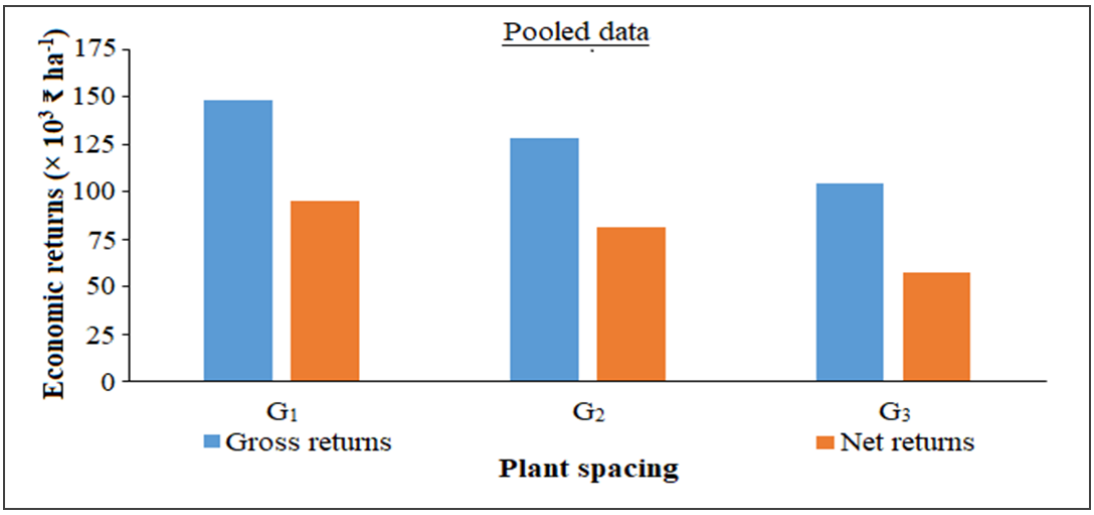
Similarly, the maximum BCR 2.81 and 2.95 were observed under G_1 plant spacing during the year 2019 and in pooled data of two years respectively, which was significantly and 15.0%, 39.1% and 10.1%, 35.3% higher over G_2 and G_3 plant spacings during the year 2019 and in pooled data of two years respectively.

Among seed priming the BCR 3.11 was maximum and it was observed under consortium bio-fertilizer seed primed spring groundnut during the year 2018 and significantly higher over the BCR of remaining seed primed treatments.

Similarly, during the year 2019 and in pooled data of two years, the maximum BCR of 2.85 and 2.97 were observed under consortium bio-fertilizer seed primed spring groundnut respectively, which were significantly higher over rest of the seed primed treatments. But during 2019 the observed BCR was at par with T_3 and significantly higher over rest of the seed primed treatments.

The higher pod and haulm yield of groundnut under G_1 plant spacing and in consortium bio-fertilizer seed primed treatment resulted higher gross and net returns. Due to similar cost of cultivation under all plant spacings and seed priming treatments, the above treatments reported higher BCR. Arif *et al* (2016) reported the similar results that, the significantly higher B:C ratio of 2.85 was recorded in crop sown under normal spacing 30 cm × 10 cm in 90 cm dripline which would be the result of higher gross and net returns given by the crop raised under above crop geometry.





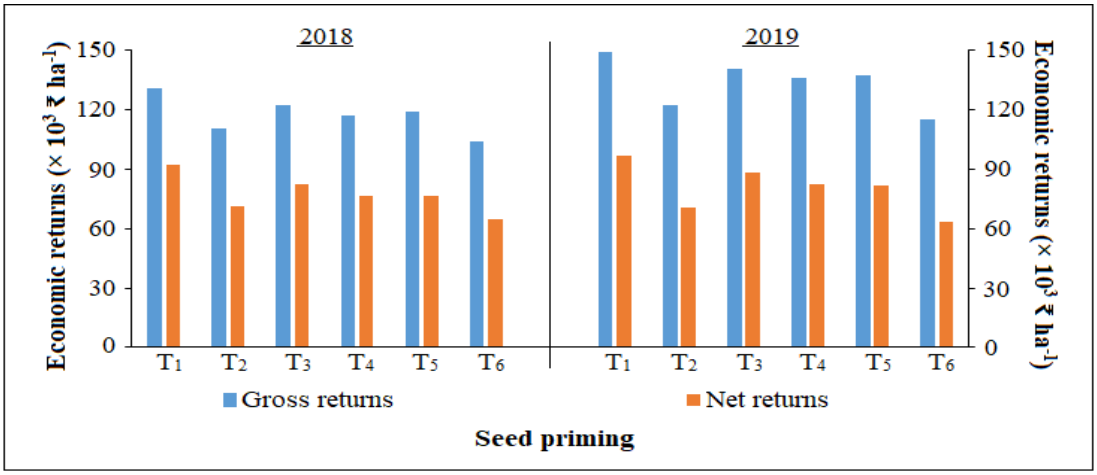


Figure 4.2: Effect of seed priming and plant spacing on gross returns and net returns (₹ ha^{-1}) of spring groundnut

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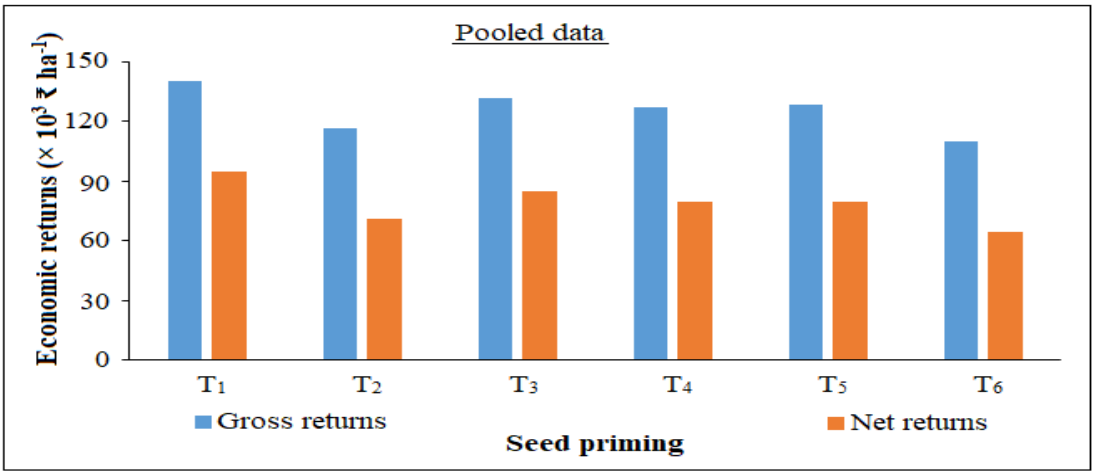
Figure 4.2 contd…



Similarly, Abdelrahman and Jens (2011) reported that, the hydro primed crop of groundnut and cowpea were reported significantly higher B:C ratio (1.48 and 1.20 respectively) compared to non-primed crop. They further reported that the higher crop yield under hydro-priming treatment given higher returns even their cultivation cost was same.

The interactional effect among seed priming and plant spacing were found to be non-significant.

4.5 Plant analysis

4.5.1 Haulm and Kernel N content

The data pertaining N content and uptake by spring groundnut haulm and kernel were presented in Table 4.13. During the year 2018, the higher N content of spring groundnut haulm (1.67%) and kernel (4.23%) was observed under the crop cultivated under G_3 crop geometry.

Similarly, the N content of haulm and kernel was 1.64% and 4.17% during 2019 and 1.66% and 4.20% in pooled data of two years respectively. But all plant geometries showed a non-significant difference during both the crop season 2018, 2019 and in pooled data of two years.

Among seed priming during the year 2018, the highest N content in haulm (1.73%) and kernel (4.24%) was noticed in the consortium bio-fertilizer primed spring groundnut.

During the year 2019 and in pooled data of two years, it was observed that 1.62% and 1.68% N content in haulm and 4.18% and 4.21% N content in kernel respectively. The lowest N content in both haulm and kernel of spring groundnut was noticed in control (T_6) treatment, but all the seed primed treatments were at par with each other during the year 2018, 2019 and in pooled data of two years.

The interactional effect among seed priming and plant spacing were found to be non-significant.

4.5.2 Haulm and Kernel N uptake

The spring groundnut grown under G_1 plant spacing uptake higher N in haulm (119.0 kg ha^{-1}) which was at par with the haulm N uptake of the crop grown in G_2 plant spacing, but significantly differ from G_3. The N uptake by kernel (178.4 kg ha^{-1}) under G_1 crop spacing during the year 2018 was significantly higher over both G_2 and G_3 crop spacings.

A similar trend was observed during the year 2019 and in pooled data of two years, under same plant spacing. The maximum haulm N uptake of 140.0 kg ha^{-1} and 129.5 kg ha^{-1} and kernel N uptake of 182.9 kg ha^{-1} and 180.6 kg ha^{-1} were reported under G_1 plant spacing during the year 2019 and in pooled data of two years respectively. which was significantly higher than the N uptake of remaining crop geometries.

During the year 2018, maximum uptake of N was observed in consortium bio-fertilizer seed primed spring groundnut haulm (136.8 kg ha^{-1}) and kernel (169.6 kg ha^{-1}).

Similarly, the same treatment uptake higher haulm N (133.9 kg ha^{-1} and 135.4 kg ha^{-1}) and kernel N (174.1 kg ha^{-1} and 171.9 kg ha^{-1}) of spring groundnut during 2019 and in pooled data of two years respectively. The consortium bio-fertilizer treatment reported significantly higher N uptake in both haulm and kernel treatment during the year 2018, 2019 and in pooled data of two years. But during 2019, the kernel N uptake of consortium bio-fertilizer primed crop of was at with T_3 seed primed treatment.

During both the years 2018, 2019 and in pooled data of two years, the spring groundnut grown under G_1 plant spacing and seed primed with consortium bio-fertilizer recorded a significantly higher N uptake in both haulm and kernel over rest of the plant spacing and seed priming treatments. The higher N (kg ha^{-1}) was due to high haulm and pod yield under G_1 plant spacing and in consortium bio-fertilizer seed primed treatment.

The results were in accordance with the findings of Gohil *et al* (2017), they confirmed that the green gram raised under 30 cm x 10 cm plant spacing with seed priming reported 5% and 25% higher stover and seed yield over 30 cm x 10 cm plant spacing without seed priming and 30 cm x 20 cm plant spacing with and without seed priming. Which was recorded significantly higher N (53.6 kg ha^{-1}) uptake compared to rest of the treatments even though their N (%) were at par with other treatments.

The interactional effect among seed priming and plant spacing were found to be non-significant.

4.5.3 Haulm and Kernel P content

The data pertaining P content and uptake by spring groundnut haulm and kernel was presented in Table 4.14. During the year 2018, the higher P content in spring groundnut haulm (0.23%) and kernel (0.49%) was observed under G_3 crop geometry.

Table: 4.13 Effect of seed priming and plant spacing on spacing on haulm and kernel N content (%) and uptake (kg ha^{-1}) of spring groundnut

Treatment	Haulm N (%)			Haulm N (kg ha^{-1})			Kernel N (%)			Kernel N (kg ha^{-1})		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
Plant spacing												
G_1- 22.5 cm × 20.0 cm	1.64	1.64	1.64	119.0	140.0	129.5	4.21	4.15	4.18	178.4	182.9	180.6
G_2- 30.0 cm × 15.0 cm	1.66	1.64	1.65	118.7	113.1	115.9	4.22	4.16	4.19	150.2	164.1	157.2
G_3- 45.0 cm × 10.0 cm	1.67	1.64	1.66	96.2	98.4	97.3	4.23	4.17	4.20	142.7	142.6	142.6
CD (p=0.05)	NS	NS	NS	7.39	9.42	2.17	NS	NS	NS	5.69	8.31	5.76
Seed priming												
T_1- Consortium bio-fertilizer	1.73	1.62	1.68	136.8	133.9	135.4	4.24	4.18	4.21	169.6	174.1	171.9
T_2- Cow urine	1.62	1.65	1.63	108.9	110.1	109.5	4.21	4.15	4.18	147.8	154.7	151.3
T_3- Vermicompost	1.63	1.64	1.64	112.3	126.8	119.6	4.23	4.17	4.20	156.0	167.4	161.7
T_4- Vermiwash	1.68	1.64	1.66	104.1	117.5	110.8	4.22	4.16	4.19	148.5	159.8	154.2
T_5- Con.bio + C.urine+ V.comp+ V.wash	1.61	1.64	1.63	108.6	113.3	110.9	4.23	4.17	4.20	148.3	168.2	158.2
T_6- Control	1.69	1.63	1.66	100.1	101.2	100.7	4.19	4.13	4.16	146.5	152.8	149.6
CD (p=0.05)	NS	NS	NS	9.57	5.81	8.78	NS	NS	NS	13.42	10.29	9.10
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

During the year 2019 and in pooled data of two years, the maximum P content of 0.29% and 0.26% in spring groundnut haulm and 0.53% and 0.51% in kernel respectively, were reported under same crop geometry. But all crop geometries showed a non-significant difference among them during both the years.

Among seed priming the highest P content in haulm (0.23%) and kernel (0.50%) was noticed in the consortium bio-fertilizer primed spring groundnut during 2018. Similarly, the maximum P content 0.28% and 0.26% in haulm and 0.56% and 0.53% in kernel during 2019 and in mean data of two years respectively, were observed in the same seed primed treatment i.e. consortium bio-fertilizer.

But the overall effect of seed priming treatments were found to be non-significant during the year 2018, 2019 and in pooled data of two years.

The interactional effect among seed priming and plant spacing were found to be non-significant.

4.5.4 Haulm and Kernel P uptake

The spring groundnut raised under G_1 plant spacing uptake higher P in haulm (24.1 kg ha^{-1}) during the year 2018, which was at par with the haulm P uptake under other plant spacing G_2 and G_3. But the kernel P uptake (13.8 kg ha^{-1}) under G_1 plant spacing was significantly higher over G_2 and G_3 plant spacings during 2018.

A similar trend was observed, that the higher P uptake i.e. 29.0 kg ha^{-1} and 26.6 kg ha^{-1} by haulm and 16.2 kg ha^{-1} and 14.8 kg ha^{-1} by kernel during the year 2019 and in pooled data of two years respectively, under G_1 plant spacing. But significantly higher P uptake by kernel under G_1 plant spacing and a non-significant difference with respect to haulm P uptake among all plant spacings were found during the year 2019 and in pooled data of two years.

During the year 2018, the significantly higher P uptake by consortium bio-fertilizer seed primed spring groundnut haulm (26.5 kg ha^{-1}) and kernel (15.4 kg ha^{-1}) was observed.

But, during the year 2019 the effect was non-significant among all seed primed treatments with respect to haulm P uptake that the consortium bio-fertilizer primed crop uptake higher P of 29.5 kg ha^{-1} in haulm. The kernel P uptake (17.9 kg ha^{-1}) during same season in consortium bio-fertilizer primed crop was significantly over rest of the seed primed treatments and in pooled data of two years, the significantly higher P uptake by haulm (28.0 kg ha^{-1}) and kernel (16.7 kg ha^{-1}) were observed under consortium bio-fertilizer seed treatment only.

The spring groundnut grown under G_1 plant spacing and seed primed with consortium bio-fertilizer recorded a significantly higher P uptake by kernels. But the P uptake by haulm showed a non-significant difference among all plant spacings during 2018, 2019 and in pooled data of two years.

Table: 4.14 Effect of seed priming and plant spacing on spacing on haulm and kernel P content (%) and uptake (kg ha^{-1}) of spring groundnut

Treatment	Haulm P (%)			Haulm P (kg ha^{-1})			Kernel P (%)			Kernel P (kg ha^{-1})		
	2018	**2019**	**Pooled**	**2018**	**2019**	**Pooled**	**2018**	**2019**	**Pooled**	**2018**	**2019**	**Pooled**
Plant spacing												
G_1- 22.5 cm × 20.0 cm	0.22	0.26	0.24	24.1	29.0	26.6	0.48	0.48	0.48	13.8	16.2	14.8
G_2- 30.0 cm × 15.0 cm	0.23	0.28	0.26	19.6	28.9	24.2	0.48	0.51	0.50	13.4	13.9	13.8
G_3- 45.0 cm × 10.0 cm	0.23	0.29	0.26	19.4	24.3	21.9	0.49	0.53	0.51	11.1	13.1	12.1
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.42	1.67	0.63
Seed priming												
T_1- Consortium bio-fertilizer	0.23	0.28	0.26	26.5	29.5	28.0	0.50	0.56	0.53	15.4	17.9	16.7
T_2- Cow urine	0.22	0.26	0.24	19.9	27.7	23.8	0.50	0.53	0.52	13.0	13.8	13.4
T_3- Vermicompost	0.23	0.28	0.26	22.7	28.4	25.5	0.46	0.52	0.49	12.1	15.3	13.7
T_4- Vermiwash	0.23	0.27	0.25	20.0	26.2	23.1	0.45	0.53	0.49	11.9	15.1	13.5
T_5- Con.bio + C.urine+ V.comp+ V.wash	0.22	0.27	0.24	19.9	28.2	23.6	0.49	0.46	0.48	12.6	12.5	12.5
T_6- Control	0.22	0.23	0.23	18.1	24.4	21.3	0.48	0.47	0.48	11.3	11.8	11.6
CD (p=0.05)	NS	NS	NS	2.30	NS	1.60	NS	NS	NS	1.50	1.30	0.70
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Among seed priming significantly higher P uptake in haulm in consortium bio-fertilizer primed crop over rest of the seed priming treatments was reported during both the years and it was due to higher haulm and pod yield under consortium bio-fertilizer seed primed crop.

The results were in accordance with the findings of Gohil *et al* (2017), they confirmed that the green gram raised under 30 cm x 10 cm plant spacing with seed priming reported 5% and 25% higher stover and seed yield over 30 cm x 10 cm plant spacing without seed priming and 30 cm x 20 cm plant spacing with and without seed priming. Which was recorded significantly higher P (11.2 kg ha^{-1}) uptake compared to rest of the treatments even though their P content (%) were at par with other treatments.

The interactional effect among seed priming and plant spacing were found to be non-significant.

4.5.5 Haulm and Kernel K content

The data pertaining K content and uptake by spring groundnut haulm and kernel was presented in Table 4.15.

During the year 2018, the maximum K content of spring groundnut haulm (0.48%) and kernel (0.73%) were observed in crop raised under G_3 crop geometry.

Similarly, the maximum K contain in haulm 0.38% and 0.43% and in kernel 0.63% and 0.68% respectively, were reported during the year 2019 and in pooled data of two years under G_3 crop geometry. But the haulm and kernel K content was at par with other two crop geometries G_1 and G_2 during the year 2018, 2019 and in pooled data of two years.

Among seed priming the highest K content in haulm (0.45%) and kernel (0.70%) was noticed in the consortium bio-fertilizer seed primed spring groundnut during 2018, but which was at par with other seed primed treatments.

During the year 2019 and in pooled data of two years, the highest K content in haulm 0.38% and 0.41% and kernel 0.63% and 0.66% respectively, were noted in the same treatment, but the showed a non-significant difference with other seed primed treatments.

The interactional effect among seed priming and plant spacing were found to be non-significant.

4.5.6 Haulm and Kernel K uptake

The data given in table 4.15 in context to haulm and kernel K uptake depicts that during the year 2018, the spring groundnut grown under G_1 plant spacing uptake higher K in haulm (46.8 kg ha^{-1}), but which was at par with the haulm K uptake of G_2 and G_3 plant spacing.

Table: 4.15 Effect of seed priming and plant spacing on haulm and kernel K content (%) and uptake (kg ha^{-1}) of spring groundnut

Treatment	Haulm K (%)			Haulm K (kg ha^{-1})			Kernel K (%)			Kernel K (kg ha^{-1})		
	2018	**2019**	**Pooled**	**2018**	**2019**	**Pooled**	**2018**	**2019**	**Pooled**	**2018**	**2019**	**Pooled**
Plant spacing												
G_1- 22.5 cm × 20.0 cm	0.44	0.37	0.40	46.8	41.2	44.0	0.71	0.62	0.66	20.6	20.9	20.8
G_2- 30.0 cm × 15.0 cm	0.46	0.36	0.41	42.6	36.5	39.6	0.74	0.61	0.67	20.0	16.7	18.6
G_3- 45.0 cm × 10.0 cm	0.48	0.38	0.43	40.0	32.6	36.3	0.73	0.63	0.68	16.6	14.9	15.8
CD (p=0.05)	NS	NS	NS	NS	1.96	1.32	NS	NS	NS	0.34	1.17	0.76
Seed priming												
T_1- Consortium bio-fertilizer	0.45	0.38	0.41	54.7	40.1	47.4	0.70	0.63	0.66	22.2	20.2	21.2
T_2- Cow urine	0.46	0.37	0.42	40.1	34.3	37.2	0.71	0.62	0.66	18.0	16.3	17.2
T_3- Vermicompost	0.46	0.38	0.42	44.4	38.8	41.6	0.76	0.63	0.70	20.3	19.3	19.8
T_4- Vermiwash	0.47	0.37	0.42	40.8	35.8	38.3	0.72	0.62	0.67	18.0	17.4	17.7
T_5- Con.bio + C.urine+ V.comp+ V.wash	0.44	0.36	0.40	38.5	38.1	38.3	0.72	0.61	0.67	18.5	16.7	17.6
T_6- Control	0.48	0.37	0.42	40.4	33.7	37.0	0.74	0.62	0.68	17.6	15.0	16.3
CD (p=0.05)	NS	NS	NS	5.00	2.80	1.90	NS	NS	NS	2.00	1.40	1.40
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

The significantly higher K uptake by the spring groundnut kernel (20.6 kg ha^{-1}) in plant spacing G_1 than G_2 and G_3 spacings.

A similar trend in haulm and kernel K uptake of spring groundnut was observed during the year 2019 and in pooled data of two years, under G_1 plant spacing. The crop under G_1 plant spacing uptake 41.2 kg ha^{-1} K and 44.0 kg ha^{-1} K by haulm and 20.9 kg ha^{-1} K and 20.8 kg ha^{-1} K by kernel during the year 2019 and in pooled data of two years respectively. The G_1 plant spacing showed significantly higher K uptake over rest of the plant geometries.

During the year 2018, the maximum K uptake was reported in consortium bio-fertilizer seed primed spring groundnut haulm (54.7 kg ha^{-1}) and kernel (22.2 kg ha^{-1}). Which was significantly higher than the K uptake of other seed primed treatments except K uptake by kernel.

The kernel K uptake by consortium bio-fertilizer treatment a non-significant difference with T_3 but significant difference with rest of the treatments.

During the year 2019 and in pooled data of two years, the significantly higher K uptake of 40.1 and 44.0 kg ha^{-1} by in haulm and 20.2 and 21.2 kg ha^{-1} by kernel respectively, were found in consortium bio-fertilizer seed primed spring groundnut.

But during the year 2019, the haulm K uptake in consortium bio-fertilizer primed crop was at par with T_3 and T_5 and at the same year the kernel K uptake was at par with T_3 but significantly differ from the rest of the seed primed treatments. In pooled data of two years the kernel K uptake was at par with T_3 seed primed treatment but significantly differ from other treatments.

During both the years 2018, 2019 and in pooled data of two years, the spring groundnut grown under G_1 plant spacing and seed primed with consortium bio-fertilizer recorded a significantly higher K uptake in both haulm (except haulm K under plant spacing during 2018) and kernel over rest of the plant spacing and seed priming treatments. The higher K uptake (kg ha^{-1}) was due to high haulm and pod yield under G_1 plant spacing and in consortium bio-fertilizer seed primed treatment.

The interactional effect among seed priming and plant spacing were found to be non-significant.

4.6 Soil analysis

4.6.1 Microbiological analysis

The data pertaining to soil enzymatic activity namely dehydrogenase and alkaline phosphatase of spring groundnut was represented in Table 4.16.

4.6.1.1 Dehydrogenase activity (µg TPF g^{-1} soil h^{-1})

During the year 2018, the dehydrogenase activity of soil under G_1 plant spacing was to the tune of 11.2 µg TPF g^{-1} soil h^{-1}, which was highest but at par with other plant spacings. A same trend during the year 2019 and in pooled data of two years, that the highest dehydrogenase activity was observed in the soil of G_1 plant spacing, which was highest among all crop geometries but at par them. The respective dehydrogenase activity to the tune of 11.2 µg TPF g^{-1} soil h^{-1} activity were observed in the soil of G_1 plant spacing.

Among seed priming the highest dehydrogenase activity 11.3 µg TPF g^{-1} soil h^{-1} was observed under consortium bio-fertilizer seed primed spring groundnut soil, but which was at pat with other seed primed treatments. During the year 2019 and in pooled data of two years, the highest dehydrogenase activity was found in same treatment and the respective dehydrogenase activity was 11.4 µg TPF g^{-1} soil h^{-1}, but which were at par with other seed primed treatments. The trend of dehydrogenase activity showed that on higher side & seed priming might affect the activities to build upto microbial population.

4.6.1.2 Alkaline phosphatase activity (µg PNP g^{-1} soil h^{-1})

During the year 2018, the alkaline phosphatase activity under G_1 plant spacing was to the tune of 22.3 µg PNP g^{-1} soil h^{-1}, which was highest but at par with other plant spacings G_2 and G_3. A same trend during the year 2019 and in pooled data of two years were observed in G_1 plant spacing which was highest but at par with other plant spacings. The respective alkaline phosphatase activity in the soil of spring groundnut under G_1 plant spacing was to the tune of 22.3 µg PNP g^{-1} soil h^{-1}.

Among seed priming during the year 2018, the highest alkaline phosphatase activity (22.7 µg PNP g^{-1} soil h^{-1}) was observed under consortium bio-fertilizer seed primed spring groundnut soil, but which was at pat with other seed primed treatments. During the year 2019 and in pooled data of two years, also the highest alkaline phosphatase activity was found in consortium bio-fertilizer seed primed spring groundnut soil (22.7 µg PNP g^{-1} soil h^{-1}), but which were at par with other seed primed treatments.

Usually soil enzymatic activity varies after long time, due to change in soil fertility (Nutrition- N, P and Organic carbon etc.) and microbial status. But due to similar inherent soil fertility and equally applied nutrients, a non-significant effect was found in both dehydrogenase and alkaline phosphatase activity of the soil under various plant spacings and seed priming treatments. Jane and Richard (1994) reported the similar results that, when wheat seeds treated with viable *Flavobacterium* P25 strain, the rhizo-sphere protease enzyme activity in soil was not-significant due to no limitation of nutrients in soil compared to untreated seed plot soil.

The interactional effect among seed priming and plant spacing were found to be non-significant.

Table: 4.16 Effect of seed priming and plant spacing soil dehydrogenase and alkaline phosphatase activity of spring groundnut

Treatment	Dehydrogenase activity (µg TPF g^{-1} h^{-1})			Alkaline phosphatase activity (µg PNP g^{-1} h^{-1})		
	2018	2019	Pooled	2018	2019	Pooled
Plant spacing						
G_1- 22.5 cm × 20.0 cm	11.2	11.2	11.2	22.3	22.3	22.3
G_2- 30.0 cm × 15.0 cm	11.2	11.2	11.2	22.7	22.7	22.7
G_3- 45.0 cm × 10.0 cm	11.0	11.0	11.0	22.1	22.1	22.1
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Seed priming						
T_1- Consortium bio-fertilizer	11.3	11.4	11.4	22.7	22.7	22.7
T_2- Cow urine	11.0	11.0	11.0	22.2	22.2	22.2
T_3- Vermicompost	11.2	11.2	11.2	22.3	22.4	22.4
T_4- Vermiwash	11.0	11.1	11.1	22.3	22.3	22.3
T_5- Con.bio + C.urine+ V.comp+ V.wash	11.2	11.3	11.3	22.5	22.5	22.5
T_6- Control	10.8	10.8	10.8	22.1	22.2	22.2
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS

4.6.2 Chemical studies

The data pertaining chemical study namely available nitrogen, phosphorus and potassium content (kg ha^{-1}) of the soil of spring groundnut was presented in Table 4.17.

4.6.2.1 Soil available N (kg ha^{-1})

During the year 2018, the highest soil available nitrogen (N) was found under G_1 plant spacing (128.2 kg ha^{-1}). A similar trend during the year 2019 and in pooled data of two years, were also found under G_1 plant spacing and the respective available N content was 130.4 and 129.3 kg ha^{-1}. But which was at par with remaining plant spacings during the year 2018,2019 and in pooled data of two years.

Among seed priming the highest soil available N (129.7 kg ha^{-1}) was found in

consortium bio-fertilizer seed primed spring groundnut during the year 2018, but which was at par with each other treatments. During the year 2019 and in pooled data of two years, the highest soil available N of 129.7 kg and 129.4 kg ha^{-1} respectively, were found in consortium bio-fertilizer seed primed treatment, but which were at par with other seed primed treatments.

Groundnut is a nodule forming legume crop which fixes atmospheric nitrogen by symbiotic association with *rhizobia*. Even though the crop uptakes nitrogen from the soil, the application of RDF and the addition nitrogen to soil by symbiosis process maintain the soil N level at constant level. Hence, the available N content of the soil was not affected by various seed priming and plant spacings during two-year study. Gohil *et al* (2017) showed similar results that due to cultivation of legume crops, the various plant geometries and seed priming treatments didn't have significant effect on available soil N (kg ha^{-1}) content. They further reported that even though the seed primed crop fixes more atmospheric N, the variation in soil N content was negligible compared to non-primed crop especially in green gram raised under 30 cm × 10 cm and 30 cm × 20 cm spacing with or without seed priming.

The interactional effect among seed priming and plant spacing were found to be non-significant

4.6.2.2 Soil available P (kg ha^{-1})

The highest soil available P under G_1 plant spacing (19.9 kg ha^{-1}) was found during the year 2018. During the year 2019 and in pooled data of two years, the highest soil available P of 19.9 and kg ha^{-1} were found under same plant spacing, but which was at par other two plant spacings G_2 and G_3 during the year 2018, 2019 and in pooled data of two years.

Among seed priming during the year 2018, the highest soil available P (20.0 kg ha^{-1}) was found in consortium bio-fertilizer seed primed crop, the same treatment reported highest soil available P during 2019 (19.3 kg ha^{-1}) and in pooled data of two years (19.6 kg ha^{-1}), but which was at par with other seed primed treatments during the year 2018, 2019 and in pooled data of two years.

The P was quickly fixed when applied to soil by broadcasting and its availability was reduced and their availability was continued for longer time due to slow releasing of fixed soil P over period of times. Hence, the available P content of the soil was not affected by various seed priming and plant spacings during two-year study. Choudhary *et al* (2017) also showed similar results that seed priming didn't have any effect P content of soil due to uniform uptake of P and their slow availability under both seed primed and un-primed green gram crop. Gohil *et al* (2017) also reported the negligible effect of seed priming and plant spacing on soil available P in green gram.

Table: 4.17 Effect of seed priming and plant spacing on soil available N, P and K (kg ha^{-1}) of spring groundnut

Treatment	Available N (kg ha^{-1})			Available P (kg ha^{-1})			Available K (kg ha^{-1})		
	2018	**2019**	**Pooled**	**2018**	**2019**	**Pooled**	**2018**	**2019**	**Pooled**
Plant spacing									
G_1- 22.5 cm × 20.0 cm	128.2	130.4	129.3	19.9	19.9	19.9	110.8	110.7	110.8
G_2- 30.0 cm × 15.0 cm	127.4	129.4	128.4	19.8	18.6	19.2	107.8	109.8	108.8
G_3- 45.0 cm × 10.0 cm	126.0	127.9	127.0	19.7	18.5	19.1	109.1	108.3	108.9
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Seed priming									
T_1- Consortium bio-fertilizer	129.7	129.4	129.6	20.0	19.3	19.6	112.2	114.7	113.5
T_2- Cow urine	125.3	127.3	126.3	19.7	18.8	19.3	108.5	113.7	111.1
T_3- Vermicompost	126.2	128.2	127.2	19.9	19.1	19.5	110.5	113.1	111.8
T_4- Vermiwash	127.8	125.6	126.7	19.9	18.9	19.4	110.6	112.5	111.6
T_5- Con.bio + C.urine+ V.comp+ V.wash	127.3	127.4	127.4	19.7	19.2	19.5	109.2	111.1	110.2
T_6- Control	125.2	127.2	126.2	19.8	18.6	19.2	109.5	109.2	109.4
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS

The interactional effect among seed priming and plant spacing were found to be non-significant.

4.6.2.3 Soil available K (kg ha^{-1})

During the year 2018, the highest soil available K was found under G_1 plant spacing (110.8 kg ha^{-1}). During the year 2019 (110.7 kg ha^{-1}) and in pooled data of two years (110.8 kg ha^{-1}), the highest soil, available K was found under same plant spacing, but which were at par with remaining crop geometries during both the years.

Among seed priming during the year 2018, the highest soil available K (112.2 kg ha^{-1}) was found in consortium bio-fertilizer seed primed spring groundnut. The same treatment reported higher numerical during 2019 (114.7 kg ha^{-1}) and in pooled data of two years (113.5 kg ha^{-1}), but a non-significant difference was found among all seed primed treatments during the year 2018, 2019 and in pooled data of two years.

The K was quickly fixed when applied to soil by broadcasting method and its availability was reduced, but continued for longer time due to slow releasing of fixed K over period of times. Hence, the available K of the soil was not affected by various seed priming and plant spacings during two-year study. Hence, the available K content of the soil was not affected by various seed priming and plant spacings during two-year study.

Gohil *et al* (2017) showed similar results that due to cultivation of legume crops, the various plant geometries and seed priming treatments didn't have significant effect on available soil K (kg ha^{-1}) content. They further reported that even though the seed primed crop more K from soil, the variation in soil K was negligible compared to non-primed crop especially in green gram raised under 30 cm × 10 cm and 30 cm × 20 cm spacing with or without seed priming.

The interactional effect among seed priming and plant spacing were found to be non-significant.

CHAPTER V

SUMMARY

Groundnut (*Arachis hypogaea* L.) is the most important oilseed and cash crop of India and it contributes about one third of the major oilseeds produced in the country. Groundnut is the sixth most important oilseed crop and third most important vegetable protein in the world. The botanical name of groundnut (*Arachis hypogaea* L.) was assigned by botanist Linnaus due to its leguminous nature (*Arachis*) and fruiting character below the earth surface (*Hypogea*). Groundnut belongs to family *Leguminosae* (Fabaceae) and sub-family *Papilionodeae* and it is morphologically well defined and clearly delineated from its closest relatives by the presence of geocarpic peg. Being a legume crop it is mainly classified as grain legume and oilseed crop due to its high oil content. The kernels of groundnut contain high quality edible oil (43-55%), protein (25-28%) and lower range of carbohydrates (13-16%) along with vitamins (E, K and B complex). At world level, groundnut is cultivated on 27.74 million hectare land with production of 47.10 million tonnes, with productivity of 1.69 tonnes per hectare during 2017-18 (Anonymous 2017a). India is the second largest producer of groundnut producing 9.25 million tonnes of groundnut with an average yield of 1.89 tonnes per hectare from 4.89 million hectare area, which accounting for over 18% of the world production during 2017-18 (Anonymous 2017b). In Punjab, groundnut was growing in an area about 1.2 thousand hectares with production of 2.34 thousand tonnes and productivity of 1.95 tonnes per hectare during 2017-18 (Anonymous 2017c).

Yield of any crop is a complex phenomenon, is function of genetic factor as influenced by climate and management practices. A crop with superior genetic characters, grown under congenial environmental conditions will not give better yield due to improper germination, varied plant population and plant nutrition etc. Seed priming is an important operation to achieve high percentage of germination, early and uniform emergence of crop and enhancement of ability of plants to withstand against biotic and abiotic stress conditions. Plant spacing is another key factor which regulates the growth and yield of field crops. To accommodate optimum number of plants per unit area (plant density) and to produce higher yield, ideal plant spacing is required. The proper farming procedures and density are desired to fully utilize the groundnut's genomic potential for higher yield.

The study entitled "Effect of seed priming and plant spacing on growth, productivity and soil health of spring groundnut" was carried out at Students' Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana, during spring season for two years 2018 and 2019. The experiment was conducted to evaluate the suitable seed priming and plant spacing which enhance the growth, yield, quality and productivity of spring groundnut

along with soil physical, chemical, biological properties and their interactional effect on higher productivity and economic feasibility of spring groundnut. The soil of the experimental field was neutral in pH, having normal EC, low in OC, available N and K and medium in available P. The experiment was laid out in split plot design by allocating three plant spacings viz. 22.5 cm × 20.0 cm (G_1), 30.0 cm × 15.0 cm (G_2) and 45.0 cm × 10.0 cm(G_3) in main plot and five seed priming treatments i.e. consortium bio fertilizer (T_1), cow urine (T_2), vermicompost (T_3), vermiwash (T_4), consortium bio fertilizer + cow urine+ vermi compost+ vermiwash (T_5) along with control (T_6) in sub plots with four replications. The experimental results are summarized as:

Both seed priming and plant spacing had substantial effect on the performance of spring groundnut. The data showed that emergence of spring groundnut was not affected by plant spacing but significantly affected by seed priming. Among growth parameters, plant height, no. of shoots plant^{-1} (except at harvest during 2019), dry matter accumulation plant^{-1} (except at 90 DAS during 2019) and days to 50% flowering of crop were non-significantly affected by plant spacing, but LAI was significantly affected during 2018 (at harvest) and 2019 (at 90 DAS) and at both 90 DAS and harvest in pooled data of two years. All the growth parameters were affected significantly by seed priming, except days to 50% flowering of the crop but the all interactional effect of seed priming and plant spacing were non-significant. The significantly higher plant height and LAI were recorded in consortium bio-fertilizer(T_1) seed primed crop but significantly higher no. of shoots (T_6) and dry matter accumulation plant^{-1} were recorded in control (T_6) followed by T_1. The no. of nodules plant^{-1} were also significantly higher in consortium bio-fertilizer(T_1) seed primed crop,

The yield attributes viz. no. of pegs, pods, filled pods, pod weight plant^{-1} (during 2018) and 100 kernel weight (in pooled of two years) were significantly influenced by both seed priming and plant spacing. Significantly better yield parameters were recorded in 22.5 cm × 20 cm (G_1) plant spacing and in control (T_6) among seed priming, but their effect on 100 kernel weight and no. of kernels pod^{-1} was non-significant. As result of higher yield attributes, under the plant spacing 22.5 cm × 20 cm (G_1) significantly higher pod yield, haulm yield and biological yield (quintal ha^{-1}) were recorded, but significantly higher harvest index (HI) was reported under 30 cm × 15 cm (during 2018 and in mean of two years) and 22.5 cm × 20 cm (during 2019) plant spacings. Among seed priming significantly higher numerical with respect to yield parameters were recorded in control (T_6), but due to significant effect of consortium bio-fertilizer on emergence (plant population) of spring groundnut, the Consortium bio-fertilizer(T_1) seed primed crop was recorded significantly higher pod yield, haulm yield and biological yield (q ha^{-1}) and the effect of seed priming on harvest index was non-significant.

The quality of spring groundnut viz. oil content and protein content were non-significantly influenced by both seed priming and plant spacing but the economy viz. gross returns (₹ ha^{-1}), net returns (₹ ha^{-1}) and benefit cost ratio were affected significantly. The significantly higher gross returns (₹ ha^{-1}), net returns (₹ ha^{-1}) and benefit cost ratio were reported in groundnut sown under crop geometry 22.5 cm × 20 cm (G_1) with seed priming of consortium bio-fertilizer. The haulm and kernel N, P and K (%) content of spring groundnut were non-significantly influenced by seed priming and plant spacing but their uptake (kg ha^{-1}) were affected significantly (except haulm). The significantly higher N, P and K uptake in both haulm and kernel were recorded in crop sown under geometry 22.5 cm × 20 cm (G_1) with seed priming of Consortium bio-fertilizer. The soil enzyme activity (dehydrogenase and alkaline phosphatase) and available soil N, P and K (kg ha^{-1}) after harvest of spring groundnut were non-significantly affected by seed priming and plant spacing. All the interactional effects regarding groundnut quality, economics of spring groundnut, haulm and kernel N, P, K content (%), uptake (kg ha^{-1}) and other soil physical, chemical and biological properties were influenced non-significantly by seed priming and plant spacing.

Conclusion

- The spring groundnut raised under G_1 crop geometry (22.5 cm × 20 cm) and seed primed with consortium bio-fertilizer (T_1) favored emergence and significantly influenced the yield attributes (pegs $plant^{-1}$, pods $plant^{-1}$ and filled pods $plant^{-1}$), which resulted higher pod yield, haulm yield and biological yield (q ha^{-1}) to the tune of 23.6, 23.2 and 27.0%, over G_3 crop geometry (45 cm × 10 cm) and in seed priming to the tune of 30.2, 28.8 and 29.0%, respectively, over control. However quality parameters were found to be non-significant.
- Under G_1 crop geometry (22.5 cm × 20 cm) and consortium bio-fertilizer (T_1) seed priming, the soil physical, chemical and biological properties were found to be non-significant.
- G_1 crop geometry (22.5 cm × 20 cm) and consortium bio-fertilizer (T_1) treatments, significantly influenced gross returns, net returns (₹ ha^{-1}) and B:C ratio to the tune of 35.1, 64.9 and 35.3%, over G_3 crop geometry (45 cm × 10 cm) and in seed priming to the tune of 28.2, 47.5 and 25.8%, respectively, over control.

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APPENDIX I

Weekly meteorological data recorded during *spring* season - 2018 at Meteorological Observatory, Punjab Agricultural University, Ludhiana

Standard Meteorological Week (SMW)		Temperature (^{o}C)			Relative humidity (%)			Rainfall (mm)	Total evaporation (mm)	Sun shine (hrs)	Wind speed (Km/h)
		Max.	Min.	Mean	M*	E*	Mean				
11	12 Mar – 18 Mar	29.9	14.1	22.0	85	30	58	0.0	29.8	10.0	3.0
12	19 Mar – 25 Mar	29.2	14.2	21.7	86	44	65	0.0	27.8	7.8	4.3
13	26 Mar – 01 Apr	33.1	16.5	24.8	74	29	52	0.0	38.6	10.1	4.6
14	02 Apr – 08 Apr	34.8	20.3	27.5	69	33	51	0.0	42.2	5.9	5.1
15	09 Apr – 15 Apr	33.1	18.0	25.6	73	32	53	10.0	40.5	7.4	4.7
16	16 Apr – 22 Apr	35.4	19.5	27.4	58	24	41	0.0	57.3	9.7	6.5
17	23 Apr – 29 Apr	39.6	21.5	30.5	45	19	32	0.0	62.6	11.0	5.2
18	30 Apr – 06 May	36.5	24.3	30.4	56	28	42	15.4	63.0	6.7	8.7
19	07 May–13 May	38.4	23.2	30.8	55	23	39	3.6	59.6	9.0	6.3
20	14 May–20 May	38.4	23.3	30.9	51	23	37	0.0	59	6.2	5.1
21	21 May–27 May	42.1	23.7	32.9	33	9	21	0.0	70.4	10	3.9
22	28 May – 03 Jun	40.9	27.9	34.4	45	24	35	0.0	74	7.7	10.0
23	04 Jun – 10 Jun	38.7	27.2	32.9	66	40	53	37.8	60.8	7.5	7.5
24	11 Jun – 17 Jun	37.8	23.1	32.9	61	37	49	66.8	57.8	5.2	6.0
25	18 Jun – 24 Jun	38.3	26.3	32.3	61	36	49	0.0	49.0	8.7	3.7
26	25 Jun – 01 July	34.7	27.1	30.8	67	50	58	37.2	40.2	5.1	4.7
27	02 July –08 July	33.9	26.0	29.9	85	62	73	52.8	35.7	6.9	3.9

M*- morning and E*- evening.

Weekly meteorological data recorded during *spring* season - 2019 at Meteorological Observatory, Punjab Agricultural University, Ludhiana

Standard Meteorological Week (SMW)		Temperature (°C)			Relative humidity (%)			Rainfall (mm)	Total evaporation (mm)	Sun shine (hrs)	Wind speed (Km/h)
		Max.	Min.	Mean	M*	E*	Mean				
11	12 Mar – 18 Mar	24.6	10.7	17.7	90	45	68	0.0	15.4	7.5	2.7
12	19 Mar – 25 Mar	26.9	12.9	19.9	87	42	65	0.0	23.8	7.5	3.7
13	26 Mar – 01 Apr	31.1	14.7	22.9	88	38	63	0.0	26.0	10.0	2.6
14	02 Apr – 08 Apr	34.3	18.3	26.3	83	33	59	0.0	31.2	9.4	2.6
15	09 Apr – 15 Apr	35.0	19.9	27.4	70	31	51	6.6	41.5	7.1	5.0
16	16 Apr – 22 Apr	31.3	18.1	24.7	77	37	57	31.2	30.6	8.9	3.8
17	23 Apr – 29 Apr	39.3	21.9	30.6	58	19	39	3.8	52.8	10.4	4.4
18	30 Apr – 06 May	37.7	21.3	29.5	42	15	29	4.5	53.6	9.9	4.7
19	07 May–13 May	39.4	21.9	30.7	43	17	30	3.3	62.7	9.5	4.7
20	14 May–20 May	34.5	22.1	28.3	70	34	52	11.8	48.0	7.8	4.5
21	21 May–27 May	37.7	22.4	30.0	56	24	40	0.4	52.0	10.5	5.3
22	28 May – 03 Jun	43.0	26.1	34.5	45	21	33	1.4	77.4	11.5	6.9
23	04 Jun – 10 Jun	42.7	26.6	34.6	45	26	36	0.0	74.0	11.3	4.2
24	11 Jun – 17 Jun	41	25.7	33.3	48	21	35	9.5	76.0	10.4	8.0
25	18 Jun – 24 Jun	37.2	26.0	31.6	69	39	54	19.0	54.6	8.4	5.0
26	25 Jun – 01 July	39.6	28.1	33.9	59	29	47	00	62.5	10.5	5.1
27	02 July –08 July	37.6	28.5	33.1	68	48	59	14.4	50.0	5.5	6.3

M*- morning and E*- evening.

APPENDIX II (a)

Proposed sale rates and other costs by PAU for spring 2018 and 2019 for calculating cost of cultivation of spring groundnut (ha^{-1})

	Item	Year	2018	2019
		Qty	Value (₹)	
A	Gross returns			
	i) Main product (q)	10	44500	48900
	ii) By product (q)	10	1100	1150
B	Variable costs	Qty	(₹ ha^{-1})	(₹ ha^{-1})
1	Seed and seed treatment (kg)			
	i) Seed	100	10000	13500
	ii) Bio-fertilizer (Rhizobium)	1	600	1500
	iii) Vermicompost	45	900	1900
	iv) Vermiwash (litre)	80	1900	2900
2	Manures and fertilizers (kg)			
	i) Urea	17.5	102.5	152.5
	ii) SSP	150	1086	1116
	iii) Murate of potash	42.5	807.5	852.5
	iv) Gypsum	150	1050	1050
3	Pesticides			
	i) Ekalux 25 EC (litre)	1.2	815	815
4	Irrigations (No.)	4	300	300
5	Human labour (hrs)	625	24150	28000
6	Tractor hours	7.5	3375	5687
8	Marketing charges	-	315	375
9	Intrest on variable costs@ 10 % for half period (ha^{-1})	-	1100	1250

APPENDIX II (b)

Cost of cultivation of spring groundnut (ha^{-1}) during the year 2018 and 2019

S. No.	Treatment	2018 (₹ ha^{-1})	2019 (₹ ha^{-1})
1	T_1- Consortium bio-fertilizer	43700	52500
2	T_2- Cow urine	43200	51900
3	T_3- Vermicompost	44000	53000
4	T_4- Vermiwash	45000	54000
5	T_5- Con.bio + C.urine + V.comp + V.wash	46600	55500
6	T_6- Control	43100	51100

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