EFFECT OF SEED RATE AND ROW SPACING ON QUALITY SEED PRODUCTION OF FENUGREEK (*Trigonella foenum graecum* L.)

By

Pawan Kumar

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CERTIFICATE– I

This is to certify that the thesis entitled, **"Effect of seed rate and row spacing on quality seed production of fenugreek (*Trigonella foenum graecum* L."** submitted for the degree of **Master of Science (Agriculture)** in the subject of **Horticulture-Vegetable Science** to the **Chaudhary Charan Singh Haryana Agricultural University, Hisar** is a bonafide research work carried out by **Mr. Pawan Kumar, Admn. No. 2015A104M,** under my supervision and no part of this thesis has been submitted for any other degree.

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

[Dr. S.K. Phor]
Major Advisor
Assistant Professor
Department of Vegetable Science
CCS Haryana Agricultural University
Hisar-125004 (Haryana)

CERTIFICATE – II

This is to certify that the thesis entitled, **"Effect of seed rate and row spacing on quality seed production of fenugreek (*Trigonella foenum graecum* L."** submitted by **Mr. Pawan Kumar**, **Admn. No. 2015A104M** to the **Chaudhary Charan Singh Haryana Agricultural University, Hisar** in partial fulfilment of the requirements for the degree of **Master of Science (Agriculture)** in the subject of **Horticulture-Vegetable Science** has been approved by the Student's Advisory Committee after an oral examination on the same, in collaboration with an **External Examiner.**

MAJOR ADVISOR **EXTERNAL EXAMINER**

HEAD OF THE DEPARTMENT

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CHAPTER-I

INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.), is an annual self pollinated legume crop, belongs to the tribe *Trigonellae* and family Leguminasae. It is believed to be native to the Mediterranean region, but now, it is widely cultivated in India and other parts of the world. It is a multipurpose crop grown during winter season for seed, vegetable and condiment purposes in various parts of the country. Fenugreek is widely used as fodder crop because of its ability to provide high quality forage at all stages of growth. Fenugreek is mainly cultivated for its seeds, which are used as spice (Acharya *et al*. 2008) or dye. It is a versatile and very useful crop since its every part is utilized in one or other form. It is one of the principle constituents of curry powder. The seeds of fenugreek are used as a spice due to its pleasantly bitter taste and a peculiar odour and flavour. In North India, its fresh and dried leaves with tender shoots are consumed as most popular leafy vegetable and spice since they make the food more savory and provide major calorie and other nutritional benefits.

Being multiuse seed spice crop, fenugreek is cultivated in India, Argentina, Egypt, Southern France, Morocco, Spain, Turkey, China, Algeria and Ethiopia. However, India is the main producer and exporter of fenugreek in the world (Anonymous, 2013), and hence, reckoned among the prominent fenugreek seed spice suppliers. The major importers of Indian fenugreek are Saudi Arabia, Japan, Malaysia, United States of America, United Kingdom, Singapore and Sri Lanka. In India, the major fenugreek producing states are Rajasthan, Gujarat, Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Maharashtra and Tamil Nadu. In India during 2014-15, the crop was grown over an area of 123.40 million hectares with total production of 130.80 million tonnes. Out of total area and production more than 65% area i.e. 81.70 million hectares with total production of 84.20 million tonnes of the country is produced by Rajasthan alone. In Haryana, the crop was sown in an area of 4.80 million hectare with seed production of 8.70 million tonnes during the year 2014-15 (Anonymous, 2015). Because of low water requirement, it is being grown successfully in Southwestern Haryana particularly in the districts of Hisar, Bhiwani, Rohtak, Sirsa, Mohindergarh and Rewari where the soil and climatic conditions both are favourable for its growth and development (Anonymous, 2015).

The nutritional significance of fenugreek is well recognized all over the world as a vital source of essential minerals, vitamins and dietary fibers. Seeds are rich in proteins, minerals, especially iron and calcium, vitamins particularly vitamin A, C and B_2 and contain substances like volatile oil, cellulose, starch, sugars, alkaloids and enzymes. Fenugreek seeds are rich in essential amino acids and trigonelline (150 mg/100 g) for which it is valued for

medicinal uses. Galactomannan, often found in the endosperm cell wall, are the main polysaccharide in fenugreek seeds and can comprise up to 50% of the seed weight. Increased interest in fenugreek in health-food market has been generated due to the medicinal compounds (Petropoulos, 2002), including the steroidal sapogenins, isoleucine and galactomannan (Acharya *et al*., 2006) present in leaves and seeds. Isoleucine present in fenugreek can be used metabolically as a precursor of 4-hydroxyisoleucine that regulates insulin secretion in animals (Broca *et al*., 2000). This combination with gastro-intestinal effects of dietary fibre found in the fenugreek seed accounts for most of the hypoglycemic and anti-hyperglycemic effects of fenugreek.

The medicinal properties of fenugreek were recorded by the Egyptians and Hippocrates (Lust, 1974), making it one of the oldest recorded plants used in medicine (Acharya *et al*., 2008). The seeds have the good therapeutic properties (Fazil and Hardman, 1967), against digestive disorders (Sharma *et al*., 1991), diabetes (Jain *et al*., 1987) and have the anti-fertility (Sethi *et al*., 1990) and diuretic actions too (Tanira *et al*., 1989). Its seeds are used to some extent as carminative, antipyretic, anthelmintic, tonic and cooling drink (John, 2003). The medicinal uses of fenugreek are various including wound-healing, aphrodisiac, galactogogue and expectorant. It is used in the treatment of bronchial ailments, sore throats, sciatica and irritation of skin (Lust, 1974), tumours (Sur *et al*., 2001), head lice (El-Bashier and Fouad, 2002), sickness caused by air pollution and to reduce UV-A/UV-B radiation damage to skin cells (Singh *et al*., 2004). Seeds are also used in the treatment of hypertension (Balaraman *et al*., 2006), hyperglycemia, which can help in the regulation of Type 2 diabetes (Raghuram *et al*., 1994), hypercholesterolemia (McAnuff *et al*., 2002) and as anti-inflammatory. Fenugreek minimizes the symptoms of menopause, relieves constipation, soothes sore throat pain, eases minor indigestion and relieves diarrhea. The seeds are used in colic, flatulence, dysentery, dyspepsia, chronic cough and enlargement of liver and spleen, rickets and gout.

Using this herb for increasing milk production in nursing mothers and lactating animals is not new. This mastogenic effect has long been known in various cultures throughout the world dating back to harm the girls in the Middle East. It is also used in Indian *Ayurvedic* (Sur *et al*., 2001), Siddha, Unani, Chinese, Tibetian, Greek and Arabian medicines (Evidente *et al*., 2007) as well as in Naturopathy, Aromapathy and Homeopathy (Daswani *et al*., 2003) and veterinary medicines (Sinskaya, 1961). For centuries, modern science is just becoming aware of the healthy aspects of phyto-estrogens and their role in increasing size and health of the breasts. Fenugreek oil is used in the manufacturing of hair tonics and lowering blood sugar levels. The organic fenugreek seeds are exported in their whole and

powdered forms as well as in the form of extracted oil, which is extensively used as herbal supplements, therapeutic applications, culinary, tea and perfumery.

Seeds are the foundation of agriculture but without a steady supply of high-quality seed, yields and crop quality would be greatly decreased. Seed quality is the most vital and crucial for crop production, one of the ways to increase the productivity without adding appreciably to the extent of land now under cultivation by planting quality seed. The quality seed is important for achieving the desired goal of raising the crop either yield or for resistance or for desired quality factors.

The fenugreek cultivation shall not only diversify the existing paddy-wheat cropping system but also enable the state to earn foreign exchange. Its requirement for fertilizer and irrigation is comparatively lower than other cool season vegetables as well as traditional crops like wheat and paddy. Fenugreek has wide adaptability with respect to soil and climatic conditions.

Since fenugreek is mainly grown as leafy vegetable throughout India, there is ample scope for its cultivation as seed spice. But there is lack of systematic research work on fenugreek particularly with respect to seed production. Generally the seed in fenugreek is low because of poor vegetative growth, less number of flowers and low harvest index. In order to increase the yield and productivity of this important seed spice cum leafy vegetable optimum seed rate and spacing are most important factors.

Fenugreek is very important spice crop but the productivity of this crop is very low. Not only for maximizing the productivity but also for securing the highest net returns from a unit area, maintaining optimum plant population per unit area, which depends on best possible seed rate and spacing, is considered very essential. However, very little research work has been carried out on spacing and seed rate of fenugreek seed crop. Hence, there is a considerable scope of increasing the productivity of this commercial crop by adopting the improved management practices along with optimum seed rate and spacing.

Keeping in view the importance of fenugreek in human health, the present experiment entitled **"Effect of seed rate and spacing on seed yield and its quality in fenugreek,"** was planned with the following objectives:

1. To study the effect of seed rate and row spacing on growth and seed yield of fenugreek
2. To study the effect of seed rate and row spacing on seed quality in fenugreek

CHAPTER-II

REVIEW OF LITERATURE

In India, raising the productivity and improving the seed quality are the major thrust areas in seed spices. In order to increase the export share, it is essential that fenugreek production should be increased so that besides export, the domestic consumption is not affected. This can be accomplished by adopting high yielding improved cultivars with quality seed and suitable agro-techniques. Hence, the adoption of good management practices with respect to the use of proper seed rate and row spacing is very important for increasing the yield and enhancing the quality of seed. A little work has been carried out on seed rate and row spacing. Therefore, investigations done by various research workers in relation to the present studies are reviewed in this chapter.

The available literature on fenugreek is mostly of academic nature and has least practical significance. However, in this section, the information pertaining to present study and its related aspects have been reviewed as under:

1. Growth parameters

Plant height

In fenugreek, Taneja *et al.*,(1985) showed that the different row spacing (20, 30 and 40 cm) affected the plant height of *Methi*, however, the row spacing 20 and 30 cm, which was significantly at par, provide significantly maximum plant height (65.4 and 62.6 cm) over wider row spacing of 40 cm (62.5 cm). In fenugreek, Kanwar and Saimbhi (1989) observed that the seed rate had positive effect on height of fenugreek plants, The maximum height of plant was noticed with the seed rate 12.5 kg/ha (93.5cm), which was statistically at par with the seed rate 25 kg/ha with respect to plant height. In a field experiment conducted on seed rate and fertilizer application. Toncer and Kizil (2004) noticed that seed rate significantly affect the plant height of black cumin, highest plant height was (78.8 cm) obtained from seed rate 50 kg/ha and the lowest plant height 57.0 cm and 57.1 cm obtained from seed rate of 20 kg/ha and 30 kg/ha. Murat *et al* (2005) in cumin showed the plant height was strongly influenced by seed rate and increased seed rate tends to increased in plant height, the highest plant height (40.68 cm) was obtained from the seed rate of 15 kg/ha and the lowest value (34.68 cm) with seed rate of 10 kg/ha. Moniruzzaman *et al*. (2013) reported the plant height and number of leaves/plant was found to be the highest in lower seed rate 30 kg/ha (19.34 cm) and lower in the maximum seed rate 50 kg/ha (19.16 cm) in coriander. Fahim *et al.* (2017) reported that plant height of black cumin was significantly not affected by different seed rate. In black cumin, Roussis *et al.* (2017) observed the tallest plant (20.0 cm) at a high seed rate of 60 kg/ha.

In fenugreek, Kanwar and Saimbhi (1989) reported the row spacing had a significant effect on the plant height and the maximum plant height (97.7cm) obtained at the spacing of 15 cm and the minimum plant height (92.4 cm) at the spacing of 20 cm. Plant height decreased with increased row spacing observed by Baswana and Pandita (1989). Pandita and Randhava (1994) observed in fenugreek cv. Pusa Kasuri that the significant decrease in plant height with increase in row spacing and maximum plant height (57.7 cm) recorded at a row spacing of 10 cm followed (54.4 cm) at 20 cm and (51.4 cm) at the spacing of 30 cm.. Farooqi *et al.,* (2000) reported that the maximum plant height (56.27 cm) of fenugreek was observed at the spacing of 30x30 cm. Similarly, the plant height was significantly higher with a row spacing of 30 cm as compared with a row spacing of 20 cm reported by Mavai *et al.* (2000). The maximum plant height (100.50 cm) of fenugreek cv. Hisar Sonali with a seed rate of 20 kg/ha noticed by (Meena *et al.*2003). However, Singh *et al.* (2005) observed that when the fenugreek seed sown with a spacing of 22.5 cm significantly increased the plant height (72.5 cm) over 30 cm spacing (62.3 cm). Kizil *et al.* (2008) observed the maximum plant height (22.9 cm) was obtained from the narrow row spacing (20 cm) in cumin plant. In cowpea, Taipodia *et al.* (2013) observed the tallest plant (166.7 cm) with seed rate of 25 kg/ha at row spacing of 30 cm. In coriander Sharma *et al*. (2016) noticed the tallest plant (74.01 cm) at 90 days after sowing at row spacing of 30 cm as compared to 20 and 40 cm. Tiwari *et al.* (2016) noticed that the highest plant height was obtained with the row spacing of 30x10 cm than rest other spacings. The lowest plant height recorded with the spacing of 5 cm x40 cm. Different row spacing had a significant effect on plant height, the tallest plant 87.59 cm was recorded from S_3 (40 cm spacing). The smallest plant 79.83 cm was recorded from S_1 (20 cm row spacing) observed by (Sarker *et al.,* 2017).

Number of branches per plant

In fenugreek, different seed rate had significant effect on the number of branches per plant, Brar *et al.* (1993a) observed the highest number of branches per plant (7.37) with the seed rate of 15kg/ha and minimum (5.70) with a seed rate of 25 kg/ha. Kumawat *et al.* (1998) noticed the crop sown at spacing of 30 cm produced the highest number of branches per plant as compared to a crop sown at a spacing of 20 and 40 cm. Similarly, Brar *et al.* (2005) and Singh *et al.* (2005) noticed that a fenugreek crop sown at a row spacing of 22.5 cm gave significantly higher number of branches per plant. Kizil *et al.* (2008) noticed the highest number of branches (4.9) in cumin was obtained when the plants were sown at 60 cm row spacing. In coriander, Sharma *et al*. (2016) noticed that highest number of branches obtained at 30 cm row spacing as compare to 20 and 40 cm row spacing.

In black cumin, Toncer *et al.* (2004) noticed that seed rate of 10 kg/ha had highest number of branches (9.1) as compared to the higher seed rate. In fenugreek, Deora *et al.* (2009) noticed the number of branches per plant were significantly higher with the seed rate of 2.5 kg/ha than obtained under higher seed rate. In cowpea, Taipodia *et al.* (2013) reported highest number of branches (6.4) obtained with seed rate of 25 kg/ha and row spacing of 30 cm.

Days to 50% flowering

In fenugreek the row spacing (20, 30 and 40 cm) had no significant effect on the days to 50% flowering observed by Pandita and Randhawa (1994). In coriander Sharma *et al*. (2016) noticed that earliest flowering observed at closure spacing (20 cm) as compared to wider spacing of 30 and 40 cm.

2. Yield parameters

Number of pods per plant

In fenugreek, a significant decrease in number of pods per plant with increasing in the seed rate was reported by Kanwar and Saimbhi (1989) the seed rate 12.5 kg/ha provide the maximum number of pods per plant (411.5), which were significantly higher as compared with a seed rate 25 (375.0) 37.5 (347.4) and 50 kg/ha (318.5).

In fenugreek, Taneja *et al*. (1985) observed the seed rates of 30 and 45 kg/ha, gave significantly highest number of pods per plant (19.7) and (17.4), respectively as compared with a seed rate of 60kg/ha. In fenugreek, Kanwar and Saimbhi (1989) noticed that fenugreek sown at a spacing of 20 cm gave maximum number of pods per plant (424.3) followed by a row spacing of 15 cm (411.1) and 10 cm (383.9). Mohamed *et al.* (1990) stated that the number of pods per plant increased significantly when fenugreek was sown at a spacing of 20cm. In fenugreek, Brar *et al*. (1993a) received significantly higher number of pod per plant (31.47) with a seed rate of 15 kg/ha, which was statistically at par with a seed rate of 20 (28.67) and 25 kg/ha (26.22). Similar results also obtained by Chaudhary *et al.* (1999) in field experiment on seed rate of fenugreek cv. RMt-1 observed the highest number of pods per plant with a seed rate 15 kg/ha.

In fenugreek, Halesh *et al.* (2000) noticed that the maximum number of pods per plant (50.9) with row spacing of 15 cm. However, Sharma (2000) recorded maximum number of pods per plant with a spacing of 60 x7.5 cm. Yadav *et al*. (2000) reported that the sowing of fenugreek cv. HM-65 at the spacing of 30 cm significantly increased the number of pods per plant as compared to 45 cm row spacing. The crop geometry of 30 x 10 cm provide significant improved in the number of pods per plant compare to 22.5 x 13.3 cm reported by (Chaudhary, 2006). Nandal *et al*. (2007) noticed that the sowing of seed at 40 x 5cm spacing

provide higher number of pods per plant. Bommi *et al.* (2010) noticed the maximum number of pods per plant (27.17) with a seed rate of 40 kg/ha.

In cowpea, Taipodia *et al.* (2013) reported the interaction of seed rate and row spacing they obtained highest number of pods per plant (12.3) from seed rate of 30 kg/ha and row spacing of 30 cm. In fenugreek, Bairagi (2014) noticed the maximum number of pods per plant (29.4) obtained with a row spacing of 40cm as compared with other spacing. Meena *et al.* (2016) observed that the highest number of pods per plant obtained at a row spacing of 30x10 cm. Tiwari *et al*. (2016) observed that significantly higher number of pods per plant with row spacing of 30 cm x 10 cm than rest other spacing except plant spacing 25 cm x 10 cm which was reported at par with plant spacing 30 cm x 10 cm. The lowest number of pods per plant was recorded in 5 cm x 10 cm plant spacing of fenugreek.

Pod length

In fenugreek Kanwar and Saimbhi (1989) recorded the crop geometry 30x10 cm gave significant increase in pod length (11.28 cm) as compare with the 22.5 cm x 13.3 cm (10.24 cm). In fenugreek, Brar *et al.* (2005) conducted a field trial to record the effect of sowing date and row spacing (22.5 and 30 cm) on the cv. ML-50, observed the fenugreek seed sown at the closer spacing resulted in significantly higher pod length.

Number of seeds per pod

In fenugreek, Bommi *et al*. (2010) noticed that the highest number of seeds per pod obtained when sown the fenugreek crop at the seed rate of 40 kg/ha.

The row spacing of 30 cm found significantly superior over the spacing of 40 cm with respect to number of seeds per pod in fenugreek cv. HM 65 reported by Yadav *et al.* (2000). However, maximum number of seeds per pod obtained with the spacing of 60 x 7.5 cm reported by Sharma (2000). Halesh *et al.* (2000) conducted a field experiment on fenugreek to observe the effect of spacing (15x15 cm, 30x15 cm and 30x30 cm) and they recorded that the maximum number of seeds (15.43) obtained with a spacing of 15x15cm. Singh *et al.* (2005) noticed the higher number of seeds per pod (11.7) was obtained with the fenugreek seed sown at a closer row spacing of 22.5 cm. Chaudhary (2006) observed the effect of crop geometry and noticed the crop sown at a spacing of 30x10 cm produced higher number of seeds per pod. In cowpea, Taipodia *et al.* (2013) reported the highest number of seeds per pod (12.1) obtained from seed rate of 30 kg/ha and row spacing of 30 cm.

In fenugreek, Bairagi (2014) noticed the fenugreek sown at the row spacing of 20, 30 and 40 cm had no significant role in increasing the number of seeds per pod but it depends on different genotypes. Meena *et al*. (2016) observed the number of seeds (17.3) were higher at narrow spacing (22x10 cm) as compared to wider spacing.

Seed yield

In fenugreek, Relwani (1979) noticed that the maximum fodder yield and seed yield produced by seed rate of 30-35 kg/ha for the fodder and 20-25 kg/ha for the seed yield. Singh *et al.* (1980) for getting higher seed yield recommended seed rate is 15-20 kg/ha is beneficial. Seed rate did not bring the significant effect of the seed yield reported by Taneja *et al.* (1985). Chatterjee and Das (1989) reported that the seed rate of 20 kg/ha significant effect on the seed yield. Similarly highest seed yield obtained in Tamil Nadu region with a seed rate of 20 kg/ha (Anonymous 1989). However, Kanwar and Saimbhi (1989) noticed that the maximum seed yield of fenugreek with a seed rate of 37.5 kg/ha and reduction in seed yield with increases in seed rate i.e. 50kg/ha. The seed rate of 20 and 25 kg/ha produced seed yield of 17.1 and 17.7 q/ha, respectively, which were at par but significantly more than the yield obtained with a seed rate of 15 kg/ha (14.9 q/ha) reported by Brar *et al.*(1993a). Chaudhary (1999) reported that the maximum seed yield was recorded with a seed rate of 25 kg/ha. Highest seed yield produced with a seed rate of 30 kg/ha reported by (Randhawa *et al.* 1996). Mavai *et al.* (2000) obtained maximum seed yield (14.80 q/ha) with a seed rate of 25 kg/ha. In black cumin, Toncer *et al.* (2004) reported that higher seed yield (828 kg/ha) was obtained from 10 kg/ha seed rate and lowest yield obtained with 50 kg/ha seed rate. However, Bommi *et al.* (2010) observed that the highest seed yield obtained with a seed rate of 40 kg/ha. Fahim *et al.* (2017) reported that the highest seed yield 1037 kg/ha was recorded from the seed rate 10 kg/ha which was identical to 8 kg/ha 1021 kg/ha and the lowest seed yield 555.4 kg/ha was recorded from the seed rate 4 kg/ha in black cumin. In black cumin, Roussis *et al.* (2017) reported that higher seed yield (1066 kg/ha) was obtained with the seed rate of 50 kg/ha and inorganic fertilizer as compared to higher seed rate.

Row spacing (20, 30 and 40 cm) noticed the row spacing 20 and 30 cm which were recorded higher seed yield (12.32 q/ha) and (12.10 q/ha) respectively as compare lower with row spacing of 40cm (10.43q/ha) observed by Taneja *et al.* (1985). In India, the optimum productivity of fenugreek occurs at the plant spacing of 20-30 cm (Korla and Saini, 2003; Gill *et al*, 2001; Baswana and Pandita, 1989; Bhati, 1988). Similar result also presented by Bhati (1988) who was getting the maximum seed yield of *Desi* fenugreek with the spacing of 20 cm. However Kanwar and Saimbhi (1989) reported the higher seed yield with spacing of 20 cm which decreased with increased or decreased row spacing. In fenugreek, seed yield increased when the crop was grown at the spacing between 25 and 50 cm reported by Drumea and Pinzaru 1996. Maximum seed yield was obtained with a row spacing of 22.5 cm by Randhawa *et al* 1996. When the fenugreek seed were sown at the spacing of 22.5 cm highest seed yield obtained was reported by the Kumawat *et al.*1998. Highest seed yield was obtained when seed is sown at spacing of 30 x 7.5 cm observed by Sharma, 2000. Yadav *et al.* (2000) reported that when the sowing of fenugreek seed at the spacing of 30 cm significantly

improved the seed yield when compared with the row spacing in all years from 1993 to1995. However, Meena *et al* (2003) observed the sowing of fenugreek seeds at the row spacing of 30 cm increased the yield over the sowing at spacing of 20 cm. Higher seed yield of fenugreek (4.5 q/ha) at a narrow spacing (22.5 cm) over the wider row spacing 30 cm (3.5 q/ha) reported by the Singh *et al.* (2005). Fenugreek seed sown at narrow spacing produce higher seed yield over the wider spacing as reported by Gowda *et al.* 2006. Chaudhary (2006) observed crop geometry of 30x10 cm brought significantly higher seed yield (1.89 t/ha) of fenugreek over a crop geometry of 22.5x13.3 cm (1.68 t/ha). Singh *et al*. (2009) reported the higher seed yield (14.40 q/ha) in 2008-09 in fennel obtained with narrow spacing of (45 cm) and in wider spacing (60 cm) lesser the seed yield was obtained. In coriander, Sharma *et al*. (2016) noticed that higher seed yield (14.99 q/ha) obtained with a row spacing of 30 cm as compared with 20 and 40 cm.

In fenugreek, Slinkard *et al.* (2006) noticed the row spacing of 15-30 cm obtaining the maximum seed yield of fenugreek. Tuncturk (2011) reported the highest seed yield (777.0-785.0 kg/ha) was obtained from 30 cm row spacing. In cowpea, Taipodia *et al.* (2013) reported the seed rate of 30 kg/ha and wider row spacing higher seed yield (1054 kg/ha) as compared to narrow spacing and low seed rate. Bairagi (2014) reported the row spacing of 30 cm was found to be most suitable for obtaining highest seed yield in North Indian conditions. Meena *et al.* (2016) registered that the closer spacing resulting the more seed yield and biological yield over wider spacing. Tiwari *et al.* (2016) observed that significantly higher seed yield (494.45 kg/ha) obtained with the crop geometry of 20x10 cm than the crop geometry 5x10 cm and 10x10 cm.

Biological yield

In fenugreek, the seed rate significantly affect the biological yield, 25 kg/ha seed produced a biological yield of 45.2 q/ha, which was at par with a seed rate of 20 kg/ha (44.2 q/ha) but significantly higher as compared to a seed rate of 15 kg/ha (37.2q/ha) as observed by Brar *et al.* (1993a). However, fenugreek raised with a seed rate of 30 kg/ha produced a biological yield of 23.69 q/ha, which was at par with a seed rate of 25 kg/ha but significantly higher than seed rate of 15 and 20 kg/ha recorded by Chaudhary 1999. Similar effects of seed rate on biological yield of fenugreek observed by Taneja *et al*. (1985). In black cumin, Roussis *et al.* (2017) reported that higher biological yield (4063 kg/ha) was obtained with seed rate of 50 kg/ha with treatment of inorganic fertilizer.

In fenugreek Brar *et al.* (1993a) reported that a fenugreek crop sown at the spacing of 40 and 30 cm gave a stover yield of 43.9 and 43.2 q/ha, respectively, which were at par with each other but significantly higher than stover yield (39.5 q/ha) obtained at a spacing of 50 cm. Yadav *et al* (2000) noticed that sowing of fenugreek in row spacing of 30cm significantly

improved the stover yield as compared with 45 cm row spacing. Fenugreek crop was sown at a spacing of 30.0 x 10.0 cm increased stover yield by 6.4% over crop sown at a spacing of 22.5 x 13.3 cm observed by Chaudhary (2006). In coriander, Sharma *et al*. (2016) noticed the higher biological yield (41.52 q/ha) obtained with a row spacing of 30 cm as compared with 20 and 40 cm.

Harvest index

In fenugreek, Mavai *et al.* (2000) noticed that harvest index is significantly affected by the seed rate, which was found maximum with a seed rate of 20 kg/ha. However non significant effect shown by different spatial arrangement on the harvest index of fenugreek reported by Muhammad *et al.* (2005). In black cumin, Roussis *et al.* (2017) reported that higher harvest index (26.23%) was obtained with seed rate of 50 kg/ha with treatment of inorganic fertilizer. In coriander, Sharma *et al*. (2016) noticed that higher harvest index (36.06%) obtained with a row spacing of 30 cm as compared with 20 and 40 cm.

3. Quality parameters

Test weight

Use of different seed rate does not affect test weight of crop as reported by Ramdas and Muthuswami (1983). Similarly, Brar *et al.* (1993a) noticed that seed rate does not influence the test weight of seed significantly, however they obtained maximum (11.07 g) test weight with the application of 15 kg/ha and minimum (10.91g) with a seed rate of 25 kg/ha. Bommi *et al.* (2010) reported the highest test weight (11.14 g) obtained with a seed rate of 30 kg/ha.

Seed rate had no significant effect on test weight of black cumin. The test weight varies from 1.77 to 1.97 g reported by Toncer *et al.* (2004). In fenugreek, as the highest test weight was obtained from crop geometry (30 cm x 10 cm), the lowest values were obtained from 5 cm x 10 cm was reported by Singh *et al*. (2005). Chaudhary (2006) reported that the adoption of the spacing 30x10 cm brought significant increases in the test weight (12.24 g) over the crop geometry of 22.5 x 13.3 cm (12.09 g). Highest test weight recorded when the fenugreek sown at the spacing of 40 x 5 cm (9.35 g) and minimum at a spacing of 20 x 10 cm as noticed by Gowda *et al* (2006). In fenugreek, different row spacing have significant effect on mean test weight and observed the maximum test weight (9.52 g) with a row spacing of 40x5 cm, which was statistically at par with test weight (9.36 g) at a row spacing of 20x10 cm. In cowpea, Taipodia *et al.* (2013) reported the higher test weight (101.4 g) obtained from seed rate of 30 kg/ha and row spacing of 30 cm.

In fenugreek, Rana *et al* (2015) reported the crop sown at spacing at 60 cm resulted in significantly higher test weight than the lower spacing (Meena *et al.* 2016). A field

experiment conducted on two row spacing i.e. 22 x 10 cm and 30 x 10 cm and noticed that higher the seed weight(16.6 g) at the wider spacing over the narrow spacing. Sharma *et al*. (2016) noticed that higher test weight (2.78 g) obtained with a row spacing of 30 cm as compared with 20 and 40 cm. Tiwari *et al.* (2016) noticed that an experiment was conducted and reported that significantly higher test weight was observed with plant spacing of 30 cm x 10 cm than plant spacing with 5 cm x 10 cm, remaining plant spacing were reported at par with plant spacing of 30 cm x 10 cm. In black cumin, Roussis *et al.* (2017) observed that the test weight not influenced by neither seed rate nor fertilization. Despite the seed rate had no significant effect on test weight the higher seed rate produced higher results (2.70 g).

Germination percentage

To measure the germination ability of a seed lot, the International Seed Testing Association (ISTA, 1985) has proposed an excellent tool known as standard germination test. Germination test accurately predicts the field of soybean seeds when planted under ideal soil conditions that seldom exist (Tekrony, 1973). Standard germination test was also found correlated with seedling emergence and final stand at maturity in chickpea (Ram *et al*., 1989) and pigeon pea (Kharab, 1992). Germination in the laboratory tests is the emergence and development of embryo from those essential seed structures, which for kind of seed being tested indicate the ability to develop into a normal plant under favourable soil conditions (ISTA, 1999).

In fenugreek, Pandita and Randhawa (1994) observed the germination percentage remain unaffected by the different row spacing treatment. The highest germination rate (93.6%) of fenugreek seeds obtained from a crop sown at a spacing of 60 cm x7.5 cm as recorded by the Sharma (2000). Glamoclija *et al.* (2002) noticed the germination percentage is increased with the decrease in the crop density up to 50 x 10 cm followed by a decrease with further increase in crop density.

Seed vigour index-I

Measuring plumule growth as a vigour test for sugar beet was first suggested by Gem (1960). Seed vigour is one of the most important attributes of seed quality. The seeds gradually age and decline in vigour with the passage of time, which lead to the reduction in seed quality, performance and stand establishment (Christiansen and Rowland, 1981). The root and shoot length in gram was found to be significantly correlated with germination percentage in laboratory and was less correlated with field emergence (Singh and Ram, 1988). This is a major economic concern in agricultural production (McDonald, 1999). A combination of standard germination test value with seedling length provides a broad evaluation of seedling vigour. The vigour index offers the possibility of categorizing the seed lots into various classes of seed quality. The vigour index values are more significantly

correlated with the emergence rate (Verma *et al*. 1999). Similarly, Rao *et al.* (1999) showed that a seed lot with the lowest germination percentage in field had low vigour index. Various seed vigour tests have been used extensively in a number of crops to predict the planting value of seed lots in the field.

CHAPTER III

MATERIALS AND METHODS

The present study entitled "*Effect of seed rate and row spacing on quality seed production of fenugreek (Trigonella foenum graecum* L) was carried out at Research Farm of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar during the winter season of 2016-17. Seed quality analysis was done in the laboratories of Department of Seed Science and Technology, CCS Haryana Agricultural University, Hisar. The details of materials and methods used in the present study are as follows:

Climate and weather condition

Hisar is situated at latitude of 29° 10´N, longitude of 75° 46´E at altitude of 112 meters above the mean sea level and enjoys semi-arid and subtropical climate with hot and dry summer and severe cold in winter. During the course of experimentation, the values regarding minimum and maximum temperature and relative humidity are presented in Table 3.1.

Table 3.1: Agro-meteorological data during the period of experimentation on monthly basis from November 2016 to March 2017

Months	Temperature (^{0}C)		Relative humidity (%)		Rainfall (mm)
	Maximum	Minimum	Morning	Evening	
November	29.3	10.6	92	47	0.0
December	24.2	7.5	98	57	0.0
January	18.6	6.9	99	72	1.3
February	24.3	7.8	92	46	41.2
March	29.0	11.3	90	38	2.9

Source: Department of Agricultural Meteorology, CCS Haryana Agricultural University, Hisar.

Experimental Details

Design	:	Randomized Block Design (Factorial)
Replications	:	Three
Treatment combinations	:	5x3=15
Total plots	:	45
Variety	:	Hisar Sonali (The variety Hisar Sonali was a Pureline selection from a local germplasm. The experimental material was procured from department of vegetable science CCSHAU,Hisar)
Plot Size	:	4.0 m x 2.4 m
Date of sowing	:	27 November, 2016

Details of treatment

A. Seed rate **(kg/ha)**

S_1	=	16
S_2	=	18
S_3	=	20
S_4	=	22
S_5	=	24

B. Row spacing **(line to line in cm)**

R_1	=	20
R_2	=	30
R_3	=	40

Treatment combinations

R_1S_1: Seed rate 16 kg/ha at 20 cm row spacing

R_2S_1: Seed rate 16 kg/ha at 30 cm row spacing

R_3S_1: Seed rate 16 kg/ha at 40 cm row spacing

R_1S_2: Seed rate 18 kg/ha at 20 cm row spacing

R_2S_2: Seed rate 18 kg/ha at 30 cm row spacing

R_3S_2: Seed rate 18 kg/ha at 40 cm row spacing

R_1S_3: Seed rate 20 kg/ha at 20 cm row spacing

R_2S_3: Seed rate 20 kg/ha at 30 cm row spacing

R_3S_3: Seed rate 20 kg/ha at 40 cm row spacing

R_1S_4: Seed rate 22 kg/ha at 20 cm row spacing

R_2S_4: Seed rate 22 kg/ha at 30 cm row spacing

R_3S_4: Seed rate 22 kg/ha at 40 cm row spacing

R_1S_5: Seed rate 24 kg/ha at 20 cm row spacing

R_2S_5: Seed rate 24 kg/ha at 30 cm row spacing

R_3S_5: Seed rate 24 kg/ha at 40 cm row spacing

Observations recorded

During the course of experimentation, the observations were recorded for the following growth, seed yield and seed quality parameters:

1. Plant height at maturity (cm)
2. Number of branches per plant
3. Days to 50% flowering

4. Number of pods per plant
5. Pod length (cm)
6. Number of seeds per pod
7. Seed yield per plot (kg)
8. Seed yield per hectare (q/ha)
9. Biological yield (kg/plot)
10. Harvest index
11. Test weight (g)
12. Standard germination (%)
13. Seedling length (cm)
14. Seedling dry weight (mg)
15. Seed vigour index-I
16. Seed vigour index-II

The details of the methods followed for recording observations on different parameters are given below:

1. **Growth and yield parameters**

1.1 Plant height at maturity (cm)

Ten plants in each replication were randomly selected and height of these plants were measured with the help of metre scale in centimetres from base of the plant to apex of main shoot at harvesting time and average was computed.

1.2 Number of branches per plant

The numbers of primary branches of ten randomly selected plants were recorded from each replication at maturity and the value was averaged to get number of branches per plant.

1.3 Days to 50% flowering

The number of days taken from the date of sowing to flowering in 50 per cent plant under each treatment was recorded and averaged.

1.4 Number of pods per plant

The pods of ten randomly selected plants from each plot were counted at harvest and average numbers of pods per plant were recorded.

1.5 Pod length (cm)

The length of ten pods from randomly selected plants from each plot was measured and average length per pod was recorded in centimetre.

1.6 Number of seeds per pod

The seeds of ten pods from each randomly selected plant from each plot at the time of threshing were counted and the mean was recorded as average number of seeds per pod.

1.7 Seed yield per plot (kg)

The plants were harvested separately in each plot. The harvested plants were left in the field for few days to sun dry, and later, they were threshed. After cleaning, the weight of seed per (kg) plot was recorded separately.

1.8 Seed yield (q/ha)

The seed yield calculated from each plot was later converted into quintal per hectare.

1.9 Biological yield (kg/plot)

The total above ground biomass of all the plants, which were left in their respective plots after harvesting for sun drying, was weighed and the values are expressed in g/plot and later converted into the kilogram per plot.

1.10 Harvest index

The harvest index was calculated by dividing the economic yield (seed yield per plot) with the total biological yield and expressed as percentage (Donald and Hamblin, 1976).

$$\text{Harvest index} = \frac{\text{Economic yield}}{\text{Biological Yield}} \text{ X } 100$$

2. Seed quality parameters

2.1 Test weight (g)

One thousand seeds replicated thrice in each genotype were counted, weighed and average seed weight of each genotype was calculated.

2.2 Standard germination (%)

One hundred seeds of each genotype in three replicates placed between moistened towel papers (BP) and kept at 20^0C temperature in seed germinator. The first count was taken on 5^{th} day and final count on 14^{th} day and only normal seedlings were considered for percent germination computation according to the rules of International Seed Testing Association (ISTA, 1999).

2.3 Seedling length (cm)

Seedling length of ten randomly selected normal seedlings from three replications of standard germination test was measured to get the averaged seedling length in centimeters

2.4 Seedling dry weight (mg)

Seedling dry weight was assessed after the final count in the standard germination test (14 days). The ten randomly selected normal seedlings from the three replication of standard germination test were taken and dried in a hot air oven for 24hrs at 80 ± 1^0C. The dried seedlings of each replication were weighed and average seedling dry weight of each genotype was calculated.

2.5 Seedling vigour index

Seedling vigour indices were calculated according to the method suggested by Baki and Anderson (1973):

I. Vigour index-I (on seedling length basis)

Vigour index-I = Standard germination (%) X average seedling length (cm)

II. Vigour index-II (on seedling dry weight basis)

Vigour index-II = Standard germination (%) X average seedling dry weight (mg)

Statistical Analysis

The experiment was conducted in factorial randomized block design (factorial RBD). The data related to different characters were analyzed statistically by applying the analysis of Variance Technique as suggested by Cochran and Cox (1950). The critical difference, standard error and standard mean were determined at 5% level of significance as described by Panse and Sukhatme (1961).

Critical difference (CD)

For every character, the critical difference as the difference of any two mean values in order to compare the treatment means was calculated using the following formula:

$$\text{S. E. (d)} = \frac{\sqrt{2\text{MSe}}}{\text{r}}$$

$$\text{CD at 5 or 1\%} = \frac{\sqrt{2\text{MSe}}}{\text{r}} \times \text{‘t’}$$

Where,

‘t’ is the tabulated value at error degree of freedom at 5 or 1% level of significance as the case may be.

CHAPTER IV

RESULTS

The results of present experiment entitled "*Effect of seed rate and row spacing on quality seed production of fenugreek (Trigonella foenum graecum* L.)" are presented in this chapter. The data related to different parameters were statistically analyzed by using factorial Randomized block design method.

Plant height at maturity

The data presented in table 4.1 indicate that all the seed rate treatments differed significantly from each other with respect to plant height. The plant height of fenugreek at harvest improved distinctly with the increase in seed rate. The value of plant height ranged from 80.30 to 99.63 cm. The highest value of plant height was registered with seed rate of 24 kg/ha (97.93 cm) followed by seed rate of 22 kg/ha (93.12 cm), while the lowest value for plant was recorded with a seed rate of 16 kg/ha (83.24 cm).

In case of row spacing, all the treatments differed significantly from each other with respect to plant height. The plant height of fenugreek decreased significantly with increasing row spacing. The tallest plants (91.95 cm) was attained when the fenugreek seeds were sown at row spacing of 20 cm while the shortest plants (87.76 cm) were obtained with a row spacing of 40 cm.

Table 4.1: Effect of seed rate and row spacing on plant height (cm) at maturity of fenugreek

Row spacing / Seed rate	R_1 (20cm)	R_2 (30cm)	R_3 (40cm)	Mean
S_1 (16kg/ha)	85.67	83.77	80.30	83.24
S_2 (18kg/ha)	86.37	85.27	84.40	85.34
S_3 (20kg/ha)	91.60	90.50	88.60	90.23
S_4 (22kg/ha)	96.47	92.93	89.97	93.12
S_5 (24kg/ha)	99.63	98.63	95.53	97.93
Mean	91.95	90.22	87.76	

C.D. (P= 0.05) Seed rate (S) = 0.45, Row spacing (R) = 0.35, S x R =0.77.

Interaction effects of various seed rates and different row spacing on plant height showed significant variation among the treatments combinations. Significantly highest value for plant height (99.63 cm) was registered with a treatment combination S_5R_1 i.e. seed rate 24 kg/ha and row spacing 20cm while the lowest value for plant height (80.3 cm) was recorded with treatment combination S_1R_3 i.e. seed rate of 16 kg/ha and spacing of 40 cm.

Number of branches per plant

The data presented in table 4.2 showed that the effect of various seed rates and different row spacing on number of branches per plant was significant.. The number of branches per plant reduced significantly with increase in seed rate. The perusal of data reveals that the values for number of branches per plant varied from 9.6 to 12.93. In fenugreek, sowing of seeds at the rate of 16 kg/ha showed the maximum number of branches per plant (12.27) followed by a seed rate of 18 kg/ha (11.48), while with a seed rate of 24 kg/ha, the crop plants showed minimum number of branches per plant (9.94).

It is evident from the data that the effects of different row spacing differed significantly from each other concerning the number of branches per plant. The number of branches per plant improved remarkably with increasing in row spacing. The maximum number of branches per plant resulted with row spacing of 40 cm (11.42) followed by a row spacing of 30 cm (11.11). The crop sown at row spacing of 20 cm showed minimum number of branches per plant (10.69).

Table 4.2: Effect of seed rate and row spacing on number of branches per plant seed yield of fenugreek

Row spacing / Seed rate	R_1 (20cm)	R_2 (30cm)	R_3 (40cm)	Mean
S_1 (16kg/ha)	11.50	12.37	12.93	12.27
S_2 (18kg/ha)	11.27	11.40	11.77	11.48
S_3 (20kg/ha)	10.77	11.07	11.40	11.08
S_4 (22kg/ha)	10.30	10.70	10.80	10.60
S_5 (24kg/ha)	9.60	10.03	10.20	9.94
Mean	10.69	11.11	11.42	

C.D. (P= 0.05) Seed rate (S) = 0.19, Row spacing (R) =0.15, S x R =0.33.

Interaction between various seed rates and different row spacing indicated significant variation in number of branches per plant. Significantly higher value (12.93) for a number branches per plant was attained with a treatment combination of S_1R_3 i.e. seed rate 16 kg/ha and row spacing 40 cm followed by a treatment combination S_1R_2 i.e. seed rate 16 kg/ha and row spacing 30 cm (12.37) which differed significantly from other treatment combinations. The treatment combination S_5R_1 i.e. seed rate 24 kg/ha and row spacing 20 cm showed the lowest number of branches per plant (9.6).

Days to 50% flowering

In fenugreek, the seed rate and row spacing played a significant role in flowering in table 4.3. The data of days to 50% flowering varied between 81.47 and 90.8. The perusal of data indicated that various seed rates differed significantly from each other with respect to days to 50 percent flowering. The days taken to flowering in 50 percent fenugreek plants increased significantly with the increase in the seed rate. The fenugreek crop sown with a seed rate of 16 kg/ha resulted earliest flowering (83.4 days) followed by a seed rate of 18 kg/ha (84.62 days) whereas, the crop sown with a seed rate of 24 kg/ha took more number of days to flowering in 50 percent plants (88.94).

The row spacing treatments showed significant variation for days to 50 percent flowering. The days taken to flowering in 50 percent fenugreek plants decreased markedly with the increasing in row spacing. The crop raised at a row spacing of 40 cm (84.08 days) showed earliest flowering in 50 percent plants followed by a row spacing of 30 cm (85.97 days). However, the lowest value for the above character was noticed with a row spacing 20 cm (85.35 days) table 4.3.

Table 4.3: Effect of seed rate and row spacing on days to 50% flowering of fenugreek

Row spacing / Seed rate	R_1 (20cm)	R_2 (30cm)	R_3 (40cm)	Mean
S_1 (16kg/ha)	85.40	83.33	81.47	83.40
S_2 (18kg/ha)	87.43	83.93	82.50	84.62
S_3 (20kg/ha)	88.53	86.23	83.83	86.19
S_4 (22kg/ha)	89.53	87.47	85.57	87.52
S_5 (24kg/ha)	90.87	88.93	87.03	88.94
Mean	88.35	85.97	84.08	

C.D. (P= 0.05) Seed rate (S) = 0.34, Row spacing (R) =0.26, S x R =0.59.

The interaction of seed rate with row spacing showed significant variation for various treatment combinations. The treatment combination S_1R_3 (seed rate 16 kg/ha and row spacing of 40 cm) took significantly minimum number of days to 50 percent plants (81.47 days) followed by the treatment combination of S_2R_3 i.e. seed rate of 18 kg/ha and row spacing of 40 cm (82.5 days). The treatment combination S_5R_1 i.e. seed rate of 24 kg/ha and row spacing of 20 cm (90.87 days) took maximum number of days to flowering in 50 plants. In general, a seed rate of 16 kg/ha sown at a row spacing of 40 cm was found to advance flowering in fenugreek table 4.3.

Number of pods per plant

The data pertaining to the number of pods per plant have been presented in Table 4.4. The perusal data shows that the various seed rates differed significantly from each other with respect to the number of pods per plant. The values for number of pods per plant ranged from 78.47 to 98.57. The number of pods per plant had the inverse relationship with seed rate. The maximum mean value for number of pods per plant was registered with the seed rate of 16 kg/ha (92.88) followed by a seed rate of 18 kg/ha (87.61), whereas, the minimum mean number of pods per plant was registered with the seed rate of 24 kg/ha (81.56).

All the treatment for row spacing differed significantly from each other concerning the number of pods per plant. The number of pods per plant had positive correlation with row spacing. The best result with respect to the number of pods per plant when the fenugreek seed sown at a row spacing of 40 cm (91.00) followed by a row spacing of 30 cm (86.03), whereas, a row spacing of 20 cm (82.07) resulted least number of pods per plant.

Table 4.4: Effect of seed rate and row spacing on number of pods per plant of fenugreek

Row spacing / Seed rate	R_1 (20cm)	R_2 (30cm)	R_3 (40cm)	Mean
S_1 (16kg/ha)	86.30	93.77	98.57	92.88
S_2 (18kg/ha)	82.70	87.73	92.40	87.61
S_3 (20kg/ha)	81.53	85.57	89.90	85.67
S_4 (22kg/ha)	81.33	82.77	87.33	83.81
S_5 (24kg/ha)	78.47	80.30	86.80	81.86
Mean	82.07	86.03	91.00	

C.D. (P= 0.05) Seed rate (S) = 0.93, Row spacing (R) =0.72, S x R =1.60.

Interaction effect between seed rate and row spacing resulted considerable variation with respect to number of pods per plant. A seed rate of 16 kg/ha when sown at row spacing of 40 cm (98.57) observed maximum number of pods followed by a seed rate of 16 kg/ha with row spacing of 30 cm the number of pods are (93.77). The treatment combinations S_3R_1 and S_4R_1, S_2R_1 and S_3R_1, S_4R_3 and S_5R_3 were statistically at par and rest of treatment combinations differed significantly from each other.

Pod length

The data pertaining to pod length measured in cm are presented in table 4.5. The values for pod length ranged from 7.53 to 9.7 cm. The data depict that the various seed rate treatments differed significantly from each other with respect to pod length. The size of pod length decreased considerably with the increase in seed rate. The maximum mean value for

pod length was noticed with a seed rate of 16 kg/ha (9.42 cm) followed by a seed rate of 18 kg/ha (8.7 cm), while the minimum mean value for pod length (7.63 cm) was noticed with a seed rate of 24 kg/ha.

All the row spacing treatments differed significantly from each other concerning pod length. The fenugreek pod size increased significantly with the increase in row spacing. The best result with respect to pod length was obtained in fenugreek when the seed was sown at the spacing of 40 cm (8.63 cm) followed by a row spacing of 30 cm (8.49 cm), whereas, a row spacing of 20 cm attained least value (8.19 cm) for pod length.

Table 4.5: Effect of seed rate and row spacing on pod length (cm) of fenugreek

Row spacing / Seed rate	R_1 (20cm)	R_2 (30cm)	R_3 (40cm)	Mean
S_1 (16kg/ha)	9.07	9.50	9.70	9.42
S_2 (18kg/ha)	8.50	8.70	8.93	8.71
S_3 (20kg/ha)	8.20	8.40	8.60	8.40
S_4 (22kg/ha)	7.67	8.07	8.30	8.01
S_5 (24kg/ha)	7.53	7.77	7.60	7.63
Mean	8.19	8.49	8.63	

C.D. (P= 0.05) Seed rate (S) = 0.12, Row spacing (R) = 0.09, S x R = 0.21.

Interaction effect of seed rate and row spacing showed considerable variation in pod length. A fenugreek seed rate of 16 kg/ha when sown at spacing of 40cm provided the significantly best result (9.70 cm) followed by a seed rate of 16 kg/ha and sown at row spacing of 30 cm (9.5 cm), while the lowest value for pod length (7.53 cm) was registered with a treatment combination S_5R_1 i.e. seed rate of 24 kg/ha and row spacing of 20 cm. The treatment combination S_4R_1 and S_5R_1 was statistically at par and test and rest of the treatment combination differed significantly from each other.

Number of seed per pod

Seed rate showed statistically significant variation in number of seed per pod as shown in table 4.6. The values for number of seeds per pod ranged from 10.9 to 15.9. The number of seeds per pod decreased distinctly with the increase in seed rate. The table showed 15.6 as the highest mean value for number of seed per pod at seed rate of 16kg/ha followed by 14.96 at seed rate of 18 kg/ha. The least number of seed per pod (11.6) was noticed with seed rate of 24 kg/ha.

Table 4.6: Effect of seed rate and row spacing on number of seed per pod of fenugreek

Row spacing / Seed rate	R_1 (20cm)	R_2 (30cm)	R_3 (40cm)	Mean
S_1 (16kg/ha)	15.17	15.70	15.93	15.60
S_2 (18kg/ha)	14.67	14.93	15.27	14.96
S_3 (20kg/ha)	13.33	13.90	14.20	13.81
S_4 (22kg/ha)	12.50	12.80	13.77	13.02
S_5 (24kg/ha)	10.93	11.80	12.10	11.61
Mean	13.32	13.83	14.25	

C.D. (P= 0.05) Seed rate (S) = 0.18, Row spacing (R) =0.14, S x R = 0.32.

Significant variation was noticed among the row spacing treatments with respect to number of seed per pod. The seeds of fenugreek per pod increased significantly with the increasing in row spacing. The crop sown at spacing of 40 cm resulted the maximum mean value for the number of seed per pod (14.25) followed by row spacing of 30 cm (13.83), while the crop sown at row spacing of 20 cm observed least number of seed per pod (13.3) table 4.6.

Noticeable variation was observed for the interaction between seed rate and row spacing. The treatment combination S_1R_3, i.e. seed rate 16 kg/ha and row spacing 40 cm showed the best result (15.93) with respect to number of seed per pod followed by treatment combination S_1R_2 i.e. seed rate 16 kg/ha and row spacing 30 cm (15.7), S_2R_3 i.e. seed rate 18 kg/ha and row spacing 40 cm (15.26), S_1R_1 i.e. seed rate 16 kg/ha and row spacing 20 cm (15.16). The treatment combination S_5R_1 i.e. seed rate 24 kg/ha and row spacing 20 cm (10.93) noticed the lowest number of seed.

Seed yield per plot

The data pertaining to seed yield per plot have been presented in Table 4.7. The data indicated significant variation among different seed rates with respect to seed yield per plot. The value for seed yield per plot varied from 1.70 to 2.63 kg/plot. The seed yield per plot improved considerably with the increase in seed rate. The treatment *vis-à-vis* seed rate 20 kg/ha gave the maximum mean value for seed yield per plot (2.45 kg/plot) followed by a seed rate of 22 kg/ha (2.31 kg/plot), while the seed rate 16 kg/ha registered the minimum mean value for seed yield per plot (1.74 kg/plot).

Table 4.7: Effect of seed rate and row spacing on yield per plot (kg) of fenugreek

Row spacing / Seed rate	R_1 (20cm)	R_2 (30cm)	R_3 (40cm)	Mean
S_1 (16kg/ha)	1.70	1.74	1.78	1.74
S_2 (18kg/ha)	1.80	1.86	1.88	1.85
S_3 (20kg/ha)	2.15	2.58	2.63	2.45
S_4 (22kg/ha)	2.14	2.28	2.53	2.32
S_5 (24kg/ha)	1.99	2.15	2.35	2.16
Mean	1.96	2.12	2.24	

C.D. (P= 0.05) Seed rate (S) = 0.02, Row spacing (R) = 0.02, S x R = 0.04.

The levels of row spacing, i.e., 20, 30 and 40 cm, differed significantly from each other with respect to seed yield per plot. The seed yield per plot showed positive correlation with row spacing. The maximum mean value for seed yield per plot was recorded when the seed was sown at a row spacing of 40 cm (2.24 kg/plot) followed by a row spacing of 30 cm (2.12 kg/plot), while the minimum mean value for seed yield per plot (1.96 kg/plot) was registered with a row spacing of 20 cm.

Interaction effect of various seed rates and different levels of row spacing showed noticeable variation with respect to seed yield per plot. Interaction of seed rate 20 kg/ha and row spacing 40 cm showed the maximum seed yield (2.63 kg/plot) followed by a seed rate of 22 kg/ha sown at 40 cm row spacing (2.53 kg/plot) and 20 kg seed rate with 30 cm row spacing (2.58 kg/plot). The treatment combination S_1R_1 and S_2R_1, S_4R_1 and S_3R_1 were statistically at par and rest of treatment combinations differed significantly from each other. The seed rate 16 kg/ha and row spacing of 20 cm fenugreek sown sowing minimum yield per plot (1.69 kg/plot).

Seed yield per hectare (q/ha)

The data regarding seed yield of fenugreek as influenced by various seed rates and different row spacing have been presented in Table 4.8. The data showed significant variation among the levels of seed rate concerning seed yield per hectare. The seed yield per hectare increased significantly with the increase in seed rate. The value for seed yield varied from 17.59 to 27.29 q/ha. The treatment S_3, i.e., seed rate 20 kg/ha, showed the maximum mean value for seed yield per hectare (25.43 q/ha) followed by a seed rate of 22 kg/ha (23.98 q/ha), while the treatment S_1, i.e., seed rate 16 kg/ha, recorded the minimum mean value for seed yield per hectare (18.03 q/ha).

The levels of row spacing, i.e., 20, 30 and 40 cm, differed significantly from each other with respect to seed yield. The seed yield per hectare increased remarkably with the increase in row spacing. The maximum mean seed yield per hectare was recorded when the

fenugreek seed was sown at a row spacing of 40 cm (23.18 q/ha) followed by a row spacing of 30 cm (21.96 q/ha), while the minimum seed yield per hectare (20.27 q/ha) was recorded with a row spacing of 20 cm.

Table 4.8: Effect of seed rate and row spacing on yield per hectare (q/ha) of fenugreek

Row spacing / Seed rate	R_1 (20cm)	R_2 (30cm)	R_3 (40cm)	Mean
S_1 (16kg/ha)	17.59	18.03	18.47	18.03
S_2 (18kg/ha)	18.70	19.24	19.52	19.15
S_3 (20kg/ha)	22.26	26.74	27.29	25.43
S_4 (22kg/ha)	22.17	23.56	26.22	23.98
S_5 (24kg/ha)	20.62	22.23	24.38	22.41
Mean	20.27	21.96	23.18	

C.D. (P= 0.05) Seed rate (S) = 0.22, Row spacing (R) = 0.17, S x R = 0.37.

Interaction between different levels of seed rate and row spacing showed noticeable variation regarding seed yield. The treatment combination S_3R_3, i.e., seed rate 20 kg/ha when sown at a row spacing of 40 cm, showed the highest seed yield (27.29 q/ha) followed by a treatment combination S_3R_2, i.e., seed rate 20 kg/ha sown at 30 cm row spacing (26.74 q/ha). The treatment combination, S_4R_1 and S_3R_1 were statistically at par and rest of treatment combinations differed significantly from each other. The seed rate 16 kg/ha and row spacing of 20 cm fenugreek sown sowing minimum yield per plot (17.59 q/ha).

Biological yield (kg/plot)

The perusal of data presented in table 4.9 showed that all the seed rate treatments differed significantly from each other with respect to biological yield per plot. The data for biological yield ranged from 3.9 to 5.37 kg. The biological yield per plot improved significantly with increase in seed rate. The maximum mean value for biological yield per plot (5.06kg/plot) reported with seed rate of 20kg/ha followed by seed rate of 22kg/ha (4.59kg/plot), while the minimum mean value for biological yield per plot (3.92kg/plot) was recorded with a seed rate of 16kg/ha.

Table 4.9: Effect of seed rate and row spacing on biological (kg/plot) yield of fenugreek

Row spacing / Seed rate	R_1 (20cm)	R_2 (30cm)	R_3 (40cm)	Mean
S_1 (16kg/ha)	3.89	3.91	3.95	3.92
S_2 (18kg/ha)	4.12	4.13	4.16	4.14
S_3 (20kg/ha)	4.51	5.30	5.37	5.06
S_4 (22kg/ha)	4.30	4.54	4.94	4.59
S_5 (24kg/ha)	3.85	4.15	4.50	4.17
Mean	4.14	4.41	4.59	

C.D. (P= 0.05) Seed rate (S) = 0.04, Row spacing (R) = 0.03, S x R = 0.6.

The data show that a row spacing of 20, 30 and 40 cm differed significantly from each other with respect to biological yield per plot. The biological yield per plot had positive correlation with crop row spacing. The maximum mean value for biological yield (4.59 kg/plot) was obtained when the fenugreek seed sown at a spacing of 40 cm followed by row spacing of 30 cm (4.41 kg/plot), while the minimum mean value for biological yield (4.14 kg/plot)was recorded with 20 cm row spacing.

Interaction of various seed rates with different row spacing indicated remarkable variation for biological yield. The maximum value for biological yield per plot (5.37 kg/plot) was registered with 20 kg/ha seed rate and 40 cm row spacing. The treatment combinations S_2R_1 and S_3R_1, S_1R_2 and S_2R_2, S_1R_3 and S_2R_3 were statistically at par and rest of treatment combinations differed significantly from each other. The lowest value for biological yield per plot observed with seed rate 16 kg/ha and row spacing 20 cm (3.89 kg/plot).

Harvest index

The data pertaining to harvest index have been presented in table 4.10. The perusal of data reveals that all the levels of seed rate differed significantly from each with respect to harvest index. The values for harvest index varied from 43.65 to 52.17%. The harvest index of fenugreek enhanced considerably with the increase in seed rate. The maximum mean value of harvest index was recorded (51.84%) with 24 kg/ha seed rate followed by (50.26%) with seed rate of 22 kg/ha, while the minimum mean value of harvest index (44.42%) observed with 16 kg/ha seed rate.

Table 4.10: Effect of seed rate and row spacing on harvest index of fenugreek

Row spacing / Seed rate	R_1 (20cm)	R_2 (30cm)	R_3 (40cm)	Mean
S_1 (16kg/ha)	43.65	44.46	45.15	44.42
S_2 (18kg/ha)	43.86	45.11	45.34	44.77
S_3 (20kg/ha)	47.67	48.65	49.01	48.44
S_4 (22kg/ha)	49.68	49.97	51.12	50.26
S_5 (24kg/ha)	51.63	51.71	52.17	51.84
Mean	47.30	47.98	48.56	

C.D. (P= 0.05) Seed rate (S) = 0.22, Row spacing (R) = 0.17, S x R = 0.39.

All the treatments pertaining to row spacing differed significantly from each other with respect to harvest index. The harvest index of fenugreek increased significantly with the increase in row spacing. The highest mean value for harvest index was observed with a row spacing of 40 cm (48.56%) followed by 30 cm row spacing (47.98%), while the lowest value of harvest noticed under row spacing of 20 cm (47.30%).

The interaction of seed rate and row spacing differed significantly from each other with respect to harvest index. The fenugreek crop raised with a treatment combination S_5R_3 i.e. seed rate 24 kg/ha and row spacing of 40 cm resulted highest value for harvest index (52.17%) followed by S_5R_2 i.e. seed rate 24 kg/ha and row spacing 30 cm (51.71%). The treatment combinations S_1R_1 and S_2R_1, S_1R_3 and S_2R_3 were statistically at par and other treatment combination are differed significantly with each other, while the minimum value of harvest index noticed with treatment combination S_1R_1 i.e. seed rate of 16 kg/ha and row spacing of 20 cm (43.65%).

Test weight (g)

The data present in table 4.11 pertaining to the test weight. The perusal of data reveals a significant variation in test weight among different levels of seed rate. The values for test weight ranged from 9.50 to 11.70 g. The value of test weight decreased significantly with increased in seed rate. The highest mean value of test weight (11.24 g) is observed with a seed rate of 16 kg/ha followed by a seed rate of 18 kg/ha (10.64 g), while the minimum value of test weight observed under seed rate of 24 kg/ha (9.61 g).

Table 4.11: Effect of seed rate and row spacing on test weight (g) of fenugreek

Row spacing / Seed rate	R_1 (20cm)	R_2 (30cm)	R_3 (40cm)	Mean
S_1 (16kg/ha)	10.80	11.23	11.70	11.24
S_2 (18kg/ha)	10.50	10.67	10.77	10.64
S_3 (20kg/ha)	10.30	10.50	10.60	10.47
S_4 (22kg/ha)	10.10	10.20	10.40	10.23
S_5 (24kg/ha)	9.50	9.63	9.70	9.61
Mean	10.24	10.45	10.63	

C.D. (P= 0.05) Seed rate (S) = 0.14, Row spacing (R) = 0.10, S x R = 0.23.

All the levels of row spacing differed significantly from each other with respect to test weight. The test weight of fenugreek seed improved significantly with increase in row spacing. The maximum mean value for test weight (10.63 g) is observed with row spacing 40 cm followed with test weight (10.45 g) with row spacing 30 cm, while the minimum value of test weight noticed with row spacing of 20 cm (10.24g).

Interaction effect of seed rate and row spacing also showed remarkable variation among the treatment combination concerning test weight. The treatment combination S_1R_3 i.e. seed rate 16 kg/ha and row spacing 40 cm, showed the highest level of interaction effect on test weight (11.70 g) followed by treatment combination of S_1R_2 i.e. seed rate 16 kg/ha and row spacing 30 cm (11.23 g). The treatment combination of S_5R_1 i.e. seed rate 24 kg/ha and row spacing 20 cm, showed the minimum value for test weight (9.50 g).

Standard germination (%)

The study of data presented in table 4.12 reveals that all the treatments for seed rate differed significantly from each other with respect to germination percentage. The values for germination percentage varied from 87.43 to 92.13%.the germination percentage of fenugreek seeds decreased markedly with the increase in seed rate. The maximum mean value for germination percentage recorded with seed rate of 16 kg/ha (91.24%) followed by a seed rate of 18 kg/ha (90.66%) and the minimum mean value for germination percentage was noticed with a seed rate of 24 kg/ha (88.32).

The germination percentage of fenugreek seeds improved noticeably with the increased in row spacing. The row spacing levels 30 and 40 cm differed significantly from each other. The maximum germination percentage recorded with a row spacing of 40 cm

(90.59%) followed by row spacing of 30 cm (89.71%), while the minimum value for germination percentage recorded with a row spacing of 20 cm (88.81%).

Table 4.12: Effect of seed rate and row spacing on germination (%) of fenugreek

Row spacing / Seed rate	R_1 (20cm)	R_2 (30cm)	R_3 (40cm)	Mean
S_1 (16kg/ha)	90.10	91.50	92.13	91.24
S_2 (18kg/ha)	89.93	90.93	91.10	90.66
S_3 (20kg/ha)	88.80	89.53	90.93	89.76
S_4 (22kg/ha)	87.77	88.40	89.47	88.54
S_5 (24kg/ha)	87.43	88.20	89.33	88.32
Mean	88.807	89.713	90.59	

C.D. (P= 0.05) Seed rate (S) = 0.29, Row spacing (R) = 0.22, S x R = 0.50.

Interaction effect of seed rate and row spacing with respect to germination percentage also showed remarkable variation among treatment combination concerning germination percentage. The treatment combination S_1R_3 i.e. 16 kg/ha seed rate and 40 cm row spacing showed the maximum value for germination percentage (92.13%) followed by S_1R_2 i.e. seed rate 16 kg/ha and spacing 30 cm (91.50%). The minimum value for seed germination percentage was recorded with S_5R_1 i.e. 24 kg/ha seed rate and 20 cm row spacing (87.43%).

Seedling length (cm)

The perusal data presented in table 4.13 reveals a significant variation among the levels of seed rate with respect to seedling length. The data for seedling length varied from 18.40 to 21.67 cm. The maximum mean value for the above parameter was recorded with seed rate 24 kg/ha (21.3 cm) followed by seed rate of 22 kg/ha (20.72 cm), whereas, the minimum mean value observed with seed rate 16 kg/ha (19.24 cm).

The seedling length of fenugreek seeds improved significantly with the increase in row spacing. The maximum value for row spacing observed with 40 cm (20.82 cm) followed by 30 cm row spacing (20.41 cm), while the minimum value for seedling length (19.82 cm) resulted by 20 cm row spacing.

Table 4.13: Effect of seed rate and row spacing on seedling length (cm) of fenugreek

Row spacing / Seed rate	R_1 (20cm)	R_2 (30cm)	R_3 (40cm)	Mean
S_1 (16kg/ha)	18.40	19.37	19.97	19.24
S_2 (18kg/ha)	19.07	20.17	20.60	19.94
S_3 (20kg/ha)	20.30	20.50	20.80	20.53
S_4 (22kg/ha)	20.40	20.70	21.07	20.72
S_5 (24kg/ha)	20.93	21.30	21.67	21.30
Mean	19.82	20.41	20.82	

C.D. (P= 0.05) Seed rate (S) = 0.27, Row spacing (R) = 0.21, S x R = 0.47.

Interaction effect of seed rate and row spacing also showed noticeably variation among treatment combinations. The highest value for seedling length is recorded with treatment combination S_5R_3 i.e. 24 kg/ha seed rate and 40 cm row spacing (21.67 cm) followed by S_5R_2 i.e. 24 kg/ha seed rate and 30 cm row spacing (21.30 cm). S_5R_1 and S_4R_1, S_5R_2 and S_4R_2 and S_5R_3 and S_4R_3 treatment combination are statistically at par with each other. The minimum value for treatment combination observed by seed rate 16 kg/ha and row spacing 20 cm (18.4 cm) length of seedling.

Seedling dry weight (mg)

The perusal data presented in table 4.14 reveals a significant variation among the level of seed rate with respect to dry weight of seedling. The data of dry weight of seedling ranged from 66.43 to 80.60 mg. The maximum mean value for the dry weight of seedling recorded with seed rate of 24 kg/ha (78.18 mg) followed by seed rate of 22 kg/ha (76.28 mg), while the lowest value with respect to dry weight of seedling observed with seed rate of 16 kg/ha (68.31 mg).

The dry weight of fenugreek improved regularly as increased in row spacing of seed. The highest mean value of seedling dry weight recorded with the 40 cm row spacing (75.49 mg) followed by 30 cm row spacing (74.33 mg), while the lowest value of mean seedling dry weight observed with row spacing of 20 cm (70.68 mg).

Table 4.14: Effect of seed rate and row spacing on dry weight (mg) of seedling of fenugreek

Row spacing / Seed rate	R_1 (20cm)	R_2 (30cm)	R_3 (40cm)	Mean
S_1 (16kg/ha)	66.43	68.20	70.30	68.31
S_2 (18kg/ha)	68.00	72.23	73.03	71.09
S_3 (20kg/ha)	71.13	74.63	75.20	73.66
S_4 (22kg/ha)	73.07	77.63	78.13	76.28
S_5 (24kg/ha)	74.77	78.97	80.80	78.18
Mean	70.68	74.33	75.49	

C.D. (P= 0.05) Seed rate (S) = 0.58, Row spacing (R) = 0.45, S x R= 1.8010.

Interaction effect of seed rate and row spacing also showed remarkable variation among the treatment combination concerning dry weight of seedling. The treatment combination S_5R_3 i.e. 24 kg/ha seed rate and 40 cm row spacing (80.8 mg) followed by S_5R_2 i.e. 24 kg/ha seed rate and 30 cm row spacing (78.97 mg).The minimum value for treatment combination observed by seed rate 16 kg/ha and row spacing 20 cm (66.43 mg) dry weight of seedling.

Vigour index-I

The perusal data presented in table 4.15 reveals a significant variation among different seed rate with respect to vigour index-I. The data of seed vigour index-I varied from 1657.8 to 1935.5. The seed vigour index-I of fenugreek increased remarkably with increase in seed rate. The highest mean value for vigour index was recorded with a seed rate of 24 kg/ha (1881.5) followed by 22 kg/ha (1850.6), whereas, the lowest value for vigour index-I was recorded with seed rate of 16 kg/ha (1756.5).

The perusal of data pertaining to seed vigour index-I also reveals a significant among the levels of row spacing. The seed vigour index-I of fenugreek increased significantly with the increase in row spacing. The maximum mean value for seed vigour index-I (1888.1) was recorded with a row spacing of 40 cm followed by a row spacing of 30 cm (1832.5), whereas, the minimum mean value for seed vigour index-I (1762.3) observed with a row spacing of 20 cm.

Table 4.15: Effect of seed rate and row spacing on vigour index-I of fenugreek

Row spacing / Seed rate	R_1 (20cm)	R_2 (30cm)	R_3 (40cm)	Mean
S_1 (16kg/ha)	1,657.8	1,772.1	1,839.6	1,756.5
S_2 (18kg/ha)	1,714.7	1,834.0	1,870.6	1,806.4
S_3 (20kg/ha)	1,802.6	1,835.4	1,891.5	1,843.2
S_4 (22kg/ha)	1,806.0	1,842.4	1,903.3	1,850.6
S_5 (24kg/ha)	1,830.3	1,878.7	1,935.5	1,881.5
Mean	1,762.3	1,832.5	1,888.1	

C.D. (P= 0.05) Seed rate (S) = 26.24, Row spacing (R) = 20.32, S x R= 45.45

Interaction effect of seed rate and row spacing showed a considerable variation in seed vigour index-I among various treatment combinations. A treatment combination S_5R_3 i.e. seed rate 24 kg/ha and row spacing 40 cm, resulted in highest seed vigour index-I (1935.5) followed by a treatment combination of S_4R_3 i.e. seed rate 22 kg/ha and row spacing 40 cm (1903.3). The treatment combination S_1R_1 i.e. 16 kg/ha seed rate and 20 cm row spacing showed the minimum seed vigour index-I (1657.8).

Vigour index-II

The perusal data present in table 4.16 reveals a significant different among the levels of seed rate with respect to vigour index-II. The data for seed vigour index-II varied between 598 and 703. The seed vigour index-II of fenugreek increased with increased in seed rate. The maximum mean value for above parameter was observed with seed rate of 24 kg/ha (684.67) followed by 22 kg/ha (673.2) whereas, the minimum mean value of seed vigour index-II was registered with seed rate of 16 kg/ha (623.2).

The perusal data pertaining to seed vigour index-II also reveals a significant variation among the levels of row spacing. The seed vigour increased significantly as we increase in row spacing. The highest mean value for seed vigour index-II (678.4) with arrow spacing of 40 cm followed by a row spacing of 30 cm (666.4), whereas the minimum mean value for seed vigour index-II (627.4) was registered with a row spacing of 20 cm.

Table 4.16: Effect of seed rate and row spacing on vigour index-II of fenugreek

Row spacing / Seed rate	R_1 (20cm)	R_2 (30cm)	R_3 (40cm)	Mean
S_1 (16kg/ha)	598.3	624.0	647.3	623.2
S_2 (18kg/ha)	611.7	656.7	665.3	644.6
S_3 (20kg/ha)	631.7	668.3	684.0	661.3
S_4 (22kg/ha)	641.3	686.3	692.0	673.2
S_5 (24kg/ha)	654.0	696.7	703.3	684.7
Mean	627.4	666.4	678.4	

C.D. (P= 0.05) Seed Rate (S) = 4.71, Row spacing (R) = 3.65, S x R= 8.16

Interaction effect of seed rate and row spacing showed a considerable variation in seed vigour index-II among different treatment combinations. A treatment S_5R_3, i.e. seed rate 24 kg/ha and row spacing 40 cm (703.3) followed by S_5R_2, i.e. seed rate of 24 kg/ha and row spacing of 30 cm (696.7). The treatment combination S_1R_1, i.e. seed rate of 16 kg/ha and row spacing of 20 cm (598.3).

CHAPTER-V

DISCUSSION

The results obtained from the experiment entitled "*Effect of seed rate and row spacing on quality seed production of fenugreek (Trigonella foenum graecum* L.)" presented in previous chapter are discussed in this chapter under different headings. During the presentation of experimental results, significant variation was noticed due to the experimental treatments. In this chapter, the efforts have been made to establish cause and relationship amongst various parameters, which were found to be significantly influenced by different levels of seed rate and row spacing in fenugreek. In doing so, the relevant findings of other researchers have also been quoted in order to support the results of present experiment.

Plant height at maturity

In present research, sowing of seed with different rate resulted considerable increase in plant height. The results indicate that increased seed rate increased plant height of fenugreek plants, and among the seed rate, the tallest plants were observed with seed rate of 24 kg/ha. Also the maximum plant height was recorded when the crop was sown at narrow spacing i.e. 20 cm. The results of present investigation are in conformity with the findings of Mavai *et al.* (2000). Moniruzzaman *et al*. (2013) plant height and number of leaves/plant was found to be the highest in lower seed rate 30 kg/ha (19.34 cm) and lowest in the higher seed rate 50 kg/ha (19.16 cm). Similar effect shown in black cumin by Toncer and Kizil (2004) noticed that seed rate significantly affect the highest plant height was (78.8 cm) obtained from seed rate 50 kg/ha. Interaction effect of seed rate 24 kg/ha sown at 20 cm row spacing was found to the best with respect to plant height. The results confirmed the findings of Pandita and Randhawa (1994) who observed the tallest plant of fenugreek with a row spacing 20cm. Similarly, Kanwar and Saimbhi (1989) found that when decreased in row spacing from 30cm to 15cm the height of plant increased significantly. Baswana and Pandita (1989) also reported that the plant height reduced with the increase in row spacing. Similar results were also noticed by Singh *et al.* (2005) who noticed that sowing of fenugreek seed at a row spacing of 22.5 cm significantly increased plant height. In black cumin Roussis *et al.* (2017) observed the tallest plant (20.0 cm) at a high seed rate of 60 kg/ha.

However, the present results are contradictory of Meena *et al.* (2003) who observed taller plant with a row spacing of 30 cm. This might be mainly due to increased in intra and inter plant competition for nutrients, moisture, light and spacing in case of closer spacing, which adversely affect the availability of nutrients essentially required for photosynthesis, and at last, for the plant growth.

Number of branches per plant

The effect of different seed rate and various row spacing on number of branches per plant was significant in fenugreek. The maximum number of branches per plant was obtained with seed rate of 16 kg/ha. These results were confirmed with the findings of Brar *et al.* (1993a) who also registered the highest number of branches per plant with a seed rate of 15 kg/ha. These results also confirmed with the findings of Toncer and Kizil (2004) in black cumin who was noticed that seed rate of 10 kg/ha had highest number of branches (9.1) as compared to the higher seed rate

In different row spacing, the highest value for number of branches per plant was recorded with a row spacing of 40 cm. As it is explained in previous chapter, the interaction effect between the different levels of seed rate and various row spacing results significant variation. Significantly the higher number of branches per plant was attained with a treatment combination S_1R_3 i.e. seed rate of 16kg/ha and row spacing of 40 cm. Meena *et al*. (2003) observed that the number of branches per plant increased with increase in row spacing from 20 to 30 cm. Similarly, Brar *et al*. (2005) and Singh *et al.* (2005) recorded that sowing of fenugreek seed at a row spacing of 22.5 cm gave significantly higher number of branches per plant. In cumin similar result were obtained by the Kizil *et al.* (2008) when increase in row spacing increase in the number of branches per plant. The increase in number of branches per plant might be attributed to increase physiological activities like photosynthesis, cell division and cell elongation due to better exposure to sunlight and reduced competition for nutrients, moisture, light and spacing at wider row spacing. However, the results of present study those of Kumawat *et al.* (1998) who noticed that the row spacing of 30 cm produced highest number of branches per plant as compared to row spacing of 20 and 40 cm.

Days to 50 percent flowering

In present study, the seed rate and row spacing played a significant role in flowering in fenugreek. The earliest flowering recorded under the lowest seed rate of 16 kg/ha and advanced in 50 percent plants by 6.41 days in fenugreek. Among the different row spacing a row spacing of 40 cm results earliest flowering and it was found to be advanced flowering in 50 percent plants by 3.6 days. Interaction of seed rate and row spacing results significant variation among the different combination with respect to days taken to flowering in 50 percent plants. The treatment combination S_1R_3 i.e. seed rate of 16 kg/ha and row spacing of 40 cm took significantly lower number of days to attaining the 50 percent flowering in plants. The early flowering in treatment combination might be attributed to increased production of carbohydrates by the plants due to high photosynthetic activity since the plants at wider spacing had the fully expended leaf area and full exposure to sunlight, which was mainly due to less plant competition at wider spacing. However, the results of the present research are

opposite to findings of Pandita and Randhawa (1994) were observed that the row spacing (10, 20 and 30 cm) had no significant effect on days require to 50 percent flowering.

Number of pods per plant

The different levels of seed rate showed significant variation among the results of number of pods per plant in fenugreek. Among different seed rates, the seed rates of 16 kg/ha results highest number of pods per plant. Kanwar and Saimbhi (1989) gave the confirmation about the present investigation who recorded that the maximum number of pods per plant with seed rate of 12.5 kg/ha. Similar results also obtained by Brar *et al.* (1993b) and Chaudhary (1999) they were noticed that the significantly highest number of pods per plant observed with a seed rate of 15 kg/ha. All the treatments for row spacing differed significantly from each other. The best results concerning the number of pods was observed at a row spacing of 40 cm. similar results also noticed by Nandal *et al*. (2007) and observed that the seed sown at a row spacing of 40 x 5 cm gave the higher number of pods per plant.

In fenugreek, a seed rate 16 kg/ha when sown at a row spacing of 40 cm noticed significantly maximum number of pods per plant. The present investigation confirmed by the findings of Sharma (2000) who observed the highest number of pods per plant at 60 x 7.5 cm row spacing. Interaction between seed rate and row spacing noticed considerable variation among the different treatment combinations with respect to number of pods per plant. A seed rate of 16 kg/ha when sown at row spacing of 40cm results the significantly higher number of pods per plant. This might be due to less competition among the plants for nutrients, moisture, light and space for further reproductive growth of plant at wider plant spacing.

Pod length

In present study, the levels of seed rate differed significantly from each other with respect to pod length. The longest pod was observed with a seed rate of 16 kg/ha. All the row spacing treatments differed significantly from each other concerning pod length. The best result with respect to pod length was observed at row spacing of 40 cm. The results of present study support the findings Chaudhary (2006) who noticed that fenugreek seed sown at wider spacing resulted in significantly longer pod length.

Interaction effect of seed rate and row spacing results considerable variation in pod length. A fenugreek seed rate of 16 kg/ha when sown at a row spacing of 40 cm showed significantly better result. This might be due to less competition among the plants to gain nutrients from soil and easily provided space, light and moisture condition for better reproductive growth of fenugreek plant.

Number of seeds per pod

In present investigation, the seed rate treatments varied considerably with respect to the number of seed per pod. The highest number of seeds per pod was recorded with a seed rate of 16 kg/ha. The results of present research are contradictory to those of Bommi *et al*. (2010) who also observed highest number of seeds per pod with a seed rate of 40 kg/ha. Significant variation was recorded among the row spacing treatments with respect to number of seeds per pod. The crop sown at row spacing 40 cm results the maximum number of seeds per pod. The results of present study confirmed the findings of Sharma (2000) and Chaudhary (2006) who obtained the maximum number of seeds per pod under wider row spacing.

Noticeable variation with respect to number of seeds per pod was recorded for interaction between seed rate and row spacing. The treatment combination i.e. seed rate of 16 kg/ha and row spacing of 40 cm noticed the best result with respect to number of seeds per pod. The increase in number of seeds per pod might be attributed to improved vegetative growth, increased photosynthesis and greater mobilization of photosynthates towards reproductive sites due to less competition because of lesser plant population per unit area.

Seed yield per plot and per hectare

Seed yield per plot and per hectare increased with increase in seed rate but up to a level of seed rate after this slightly reduction in the yield were observed in the present investigation. The treatment with respect to seed rate 20 kg/ha provided the maximum value for seed yield per plot and per hectare. The results of present investigation substantiate the findings of Brar *et al*. (1993a) and Drumea and Pinzaru (1996) who recorded the seed yield of fenugreek increased with increase in seed rate. In fenugreek, Randhawa *et al*. (1996) also noticed that the highest seed yield obtained with a seed rate of 30 kg/ha. However, Bommi *et al*. (2010) attained the maximum seed yield with a seed rate of 40 kg/ha.

The maximum seed yield per plot and per hectare was recorded when the seed sown at row spacing of 40cm. Interaction effect between various seed rate and row showed noticeable variation for seed yield per plot and per hectare. The maximum seed yield was obtained with a seed rate of 20 kg/ha and row spacing of 40 cm. The present result support the findings of Meena *et al*. (2003) and Nandal *et al*. (2007) who noticed the sowing of fenugreek crop at wider spacing i.e. 30 and 40 cm, significantly increased the grain yield over sowing at narrow spacing, i.e. 20 cm. The increase in seed yield per plot and per hectare might be due to optimum plant population at optimum seed rate which improved vegetative growth and proper utilization of light and other nutrients at wider spacing (40 cm) and seed rate 20 kg/ha provide better germination and proper seed size and weight as compared to lower seed rate (16 and 18 kg/ha) and higher seed weight (22 and 24 kg/ha).

Biological yield

In present investigation, the biological yield was significantly influenced by various seed rate and different row spacing. It is evident from the results that the biological yield improved significantly with the increase in seed rate and the best result was observed with a seed rate of 24 kg/ha. Among the different row spacing treatments, row spacing of 40cm provided the highest biological yield. The interaction effect between various seed rate and row spacing was recorded with the interaction of seed rate 24 kg/ha and row spacing of 40 cm.

The results of present experiment are accordance with findings of Brar *et al*. (1993a) who observed that the seed rate significantly influenced the biological yield. The fenugreek crop produced significantly higher biological yield with a seed rate of 20 kg/ha as compared with 15 kg/ha seed rate. However, Chaudhary (1999) noticed that fenugreek crop sown with a seed rate of 30 kg/ha produced a biological yield at par with a seed rate of 25 kg/ha but significantly higher than the seed rate 15 and 20 kg/ha. Similar effects of seed rate on biological yield of fenugreek observed by Taneja *et al*. (1985). A fenugreek sown at a row spacing of 40 cm and 30 cm gave significantly higher biological yield than the biological yield at row spacing of 50 cm (Brar *et al*.1993a). The reason for increased biological yield with highest seed rate and widest row spacing might be due to presence of optimum plant population at optimum spacing, which brought improvement in vegetative growth of fenugreek plant.

Harvest index

The present investigation reveals an improvement in harvest index with increase in seed rate as well as row spacing. The seed rate 24 kg/ha results the highest value for harvest index. All the treatment pertaining to row spacing differed significantly from each other with respect to harvest index. The highest value for harvest index was observed with wider row spacing i.e. 40 cm. The interaction effect of seed rate and row spacing differed significantly from each other with respect to harvest index. The fenugreek seeds sown with a seed rate of 24 kg/ha at a row spacing of 40 cm results highest interaction effect regarding harvest index. The beneficial effect of seed rate on fenugreek with respect to harvest index is in accordance with the findings of Mavai *et al*. (2000) who noticed that the seed rate significantly influenced the harvest index, which was found maximum with a seed rate of 20 kg/ha. However, the results of present study are contradictory to those of Muhammad *et al*. (2005) who observed that different spatial arrangement showed non-significant effect on harvest index of fenugreek.

The increase harvest index might be attributed to increased seed yield with the increase in seed rate and crop row spacing in fenugreek. A balance between the productive

parts of plant and reserves, which form economic yield, is essential to get higher yield from a crop. A considerable increased in the yield of economic parts usually dependent on an increase in total dry matter produced by the crop. The lower harvest index with seed rate 16 kg/ha and row spacing of 20 cm might be due to increased in vegetative growth resulting higher biological yield per hectare.

Test weight

In present investigation, the test weight of fenugreek improved significantly with the decreased seed rate but improved with increase in row spacing. The experiment reveals that the significant variation for test weight among different seed rates and best result was observed with a seed rate of 16 kg/ha. Among different row spacing treatments the crop row spacing of 40 cm showed the better result with respect to test weight. Interaction effect of seed rate and row spacing also revealed that remarkable variation among the treatment combinations concerning test weight. The test weight combination S_1R_3 i.e. seed rate of 16 kg/ha and row spacing 40 cm, showed the highest level of interaction effect on test weight. The results of present investigation are similar to the findings of Brar *et al*. (1993a) who obtained the maximum test weight (11.71g) with a seed rate of 15 kg/ha and minimum (10.91 g) with a seed rate of 25 kg/ha.

Germination percentage

The present findings revealed remarkable improvement in germination percentage with reduced level of seed rate and increased level of row spacing in fenugreek. A seed rate of 16 kg/ha and row spacing of 40 cm reveals the best result with respect to germination percentage. The interaction of seed rate and row spacing with respect to germination percentage was reported significantly. The results are in agreement with findings of Sharma (2000) and Glamoclija *et al*. (2002) who noticed the highest germination percentage of fenugreek seed from a crop sown at wider row spacing as compared with narrow spacing. Increased germination percentage at wider spacing might be due to the induction of synthesis of α-amylase, protease and other hydrolytic enzymes, which appear to induce the activity of gluconeogenic enzymes during early stage of seed germination.

Seedling length

In present study the seedling length of fenugreek plant increased significantly with increase in seed rate. The longest length of seedling was obtained with seed rate of 24 kg/ha. The results revealed that a row spacing of 40 cm showed the best result with respect to seedling length. Interaction effect of seed rate and row spacing showed a considerable variation in seedling length. A treatment combination of S_5R_3, i.e. seed rate of 24 kg/ha with 40 cm row spacing resulted longest seedling length. Increased seedling length at wider

spacing might be due to the induction of photosynthesis and synthesis of α- amylase, protease and other hydrolytic enzymes which appear to induce the activity of gluconeogenic enzymes during early stage of seed germination cause lengthy of seedling. The results of present investigation were accordance in with the findings of Verrma *et al.* (1999) who reported that the Vigour Index- I is directly correlate with the seedling length i.e. higher the seedling length more the Vigour Index and vice – versa. A positive and significant correlation observed of germinability and seedling characters (root-shoot length and dry matter of seedling) resulted by (Ram *et al*., 1991; Kharab, 1992) in pigeon pea.

Seedling dry weight

In present study the seedling dry weight of fenugreek plant increased significantly with increase in seed rate. The maximum dry weight of seedling was observed with seed rate of 24 kg/ha. The results revealed that a row spacing of 40 cm showed the best result with respect to dry weight of seedling. Similarly, Singh *et al.* (1985) noticed that seed quality attributes like test weight, germination percentage, seedling dry weight and Vigour Index- II were found to be better in response to planting at a wider spacing than narrow spacing. Interaction effect of seed rate and row spacing showed a considerable variation with respect to seedling dry weight. This might be due the longer the size of seedling higher the dry weight of seedling.

Vigour index-I

In present study, the seed vigour index-I increased significantly with increased seed rate and the best result was recorded with a seed rate of 24 kg/ha. The results revealed that a row spacing of 40 cm showed the best result with respect to seed vigour index- I. Interaction effect of seed rate and row spacing showed a considerable variation in seed vigour index-I among various treatment combinations. A treatment combination S_5R_3, i.e. seed rate of 24 kg/ha and row spacing 40 cm, resulted highest seed vigour index-I.

The results of present investigation are in accordance with the findings of Verma *et al*. (1999) who observed that the seed vigour index-I is more significantly correlated with the emergence rate. A positive and significant association of germinability and seedling characters, *viz*, root-shoot length and dry matter of seedling among themselves and positive correlation with seed vigour and field emergence showed that these might be given due to consideration in prediction of seed quality and field establishment (Ram *et al* 1989*;* Kharab, 1992) in pigeon pea. The improvement in seed vigour index- I might be attributed to improved germination, which might be due to the stimulation of enzymatic activities and good seedlings growth caused by improved mobilization of food reserves.

Vigour index-II

In present study, the vigour index-II increased significantly with increased seed rate. The results revealed that a row spacing of 40 cm gave the best result with respect to vigour index-II. The interaction effect of seed rate and row spacing showed a considerable variation in seed vigour index-II among various treatment combinations. A treatment combination S_5R_3, i.e. with seed rate 24 kg/ha and row spacing 40 cm, resulted in highest seed vigour index-II. The improvement in seed vigour index-II might be due to improved germination, which might be due to stimulation of enzymatic activity and cause good seedling length that may cause higher weight of seedling and also due to which increased in seed rate doses vigour index of the crop going on increasing. Similarly, Singh *et al.* (1985) noticed that seed quality attributes like test weight, germination percentage, seedling dry weight and Vigour Index- II were found to be better in response to planting at a wider spacing than narrow spacing

CHAPTER-VI

SUMMARY AND CONCLUSIONS

The present experiment entitled *Effect of seed rate and row spacing on quality seed production of fenugreek (Trigonella foenum graecum* L.) was conducted at research farm of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar, during winter season of the year 2016-17. The seed material used for the experiment was a released variety Hisar Sonali which was procured from the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar (Haryana). The investigation comprising five levels of seed rate (16, 18, 20, 22 and 24 kg/ha) and three level of row spacing (20, 30 and 40 cm) was laid out in a randomized block design with three replications and plot size of 4.0 x 2.4 m. The important findings of the present investigation are summarized below:

Seed rate

Seed rate resulted significant improvement in all the growth, seed yield and seed quality parameters. The uppermost value for number of branches per plant, days to 50% flowering, number of pods per plant, pod length, number of seeds per pod, test weight and germination percentage were recorded with seed rate of 16 kg/ha. However, the plant height, biological yield, harvest index, seedling length, seedling dry weight, vigour index-I and vigour index-II were recorded utmost at seed rate of 24 kg/ha. Whereas, the highest seed yield per plot and per hectare were recorded with a seed rate of 20 kg/ha.

Row spacing

Different row spacing had a significant effect on growth, seed yield and seed quality parameters of fenugreek. The maximum value for plant height was recorded with row spacing of 20 cm. The number of branches per plant, days to 50% flowering, number of pods per plant, number of seeds per pod, pod length, seed yield per plot and per hectare, biological yield, harvest index, test weight, germination percentage, seedling length, seedling dry weight, vigour index-I and vigour index-II were recorded highest with a row spacing of 40 cm.

Interaction effect

Interaction of various seed rates with different row spacing resulted in remarkable variation for growth, seed yield and seed quality parameters. Significantly higher values were recorded for number of branches per plant, number of pods per plant, pod length, number of seeds per pod, test weight and germination percentage with treatment combination S_1R_3, i.e. seed rate 16 kg/ha and row spacing of 40 cm. The treatment combination S_5R_3, i.e. seed rate 24 kg/ha and row spacing of 40 cm, was found to be best with respect to biological yield, harvest index, seedling length, seedling dry weight, vigour index-I and vigour index-II.

However, the maximum seed yield per plot and per hectare recorded with treatment combination S_3R_3, i.e. seed rate 20 kg/ha and row spacing of 40 cm.

Conclusion

Based on the experimental results, it can be concluded that the various seed rate improved the growth, yield and quality of fenugreek seeds. Seed rate 20 kg/ha and row spacing 40 cm was found to be best to get higher seed yield and seed rate of 24 kg/ha and row spacing of 40 cm to get better growth and quality characteristics under semi arid conditions of Hisar (Haryana).

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ABSTRACT

Title of Thesis	:	**Effect of seed rate and row spacing on quality seed production of fenugreek (*Trigonella foenum-graecum* L.)**
Name of Degree holder	:	Pawan Kumar
Admission number	:	2015A104M
Title of Degree	:	Master of Science in Vegetable Science
Name and address of Major Advisor	:	Dr. S.K. Phor, Asst. Professor Department of Vegetable Science,KVK, Jagdishpur (Sonipat), CCS HAU, HISAR-125004
Degree awarding University	:	Chaudhary Charan Singh Haryana Agricultural University, Hisar 125004, Haryana
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Major Subject	:	Vegetable Science
Total number of pages in Thesis	:	43 + vii
Number of words in Abstract	:	421

Key words: Fenugreek, *Trigonella foenum graecum*, seed rate, row spacing, seed yield and seed quality.

The experiment entitled Effect of seed rate and row spacing on quality seed production of fenugreek (*Trigonella foenum graecum* L.) was conducted at Research Farm of Department of Vegetable Science, CCS Haryana Agricultural University, Hisar during winter season of 2016-17. The seed material used for the experiment was a released variety Hisar Sonali. The investigation comprising of five different seed rate (16, 18, 20, 22 and 24kg/ha) and three row spacing (20, 30 and 40cm) was laid out in a factorial randomized block design with three replications with a plot size of 2.4 x 4.0m. Ten competitive plants are selected randomly from each plot to record data on various attributes, which were affected significantly with different seed rate and row spacing. Seed rate resulted significant improvement in all the growth, seed yield and seed quality parameters. The uppermost value for number of branches per plant, days to 50% flowering, number of pods per plant, pod length, number of seeds per pod, test weight and germination percentage were recorded with seed rate of 16kg/ha. However, the plant height, biological yield, harvest index, seedling length, seedling dry weight, vigour index-I and vigour index-II were recorded utmost at seed rate of 24kg/ha. Whereas, the highest seed yield per plot and per hectare were recorded with a seed rate of 20kg/ha. Different row spacing had a significant effect on growth, seed yield and seed quality parameters. The maximum value for plant height was recorded with row spacing of 20cm. The number of branches per plant, days to 50% flowering, number of pods per plant, number of seeds per pod, pod length, seed yield per plot and per hectare, biological yield, harvest index, test weight, germination percentage, seedling length, seedling dry weight, vigour index-I and vigour index-II were recorded highest with a row spacing of 40cm. Interaction of various seed rates with different row spacing results remarkable variation for growth, seed yield and seed quality parameters. Significantly highest value were recorded for number of branches per plant, number of pods per plant, pod length, number of seeds per pod, test weight and germination percentage with treatment combination S_1R_3, i.e. seed rate 16kg/ha and row spacing of 40cm. The treatment combination S_5R_3, i.e. seed rate 24kg/ha and row spacing of 40cm, was found to be best with respect to biological yield, harvest index, seedling length, seedling dry weight, vigour index-I and vigour index-II. However, the maximum seed yield per plot and per hectare recorded with treatment combination S_3R_3, i.e. seed rate 20kg/ha and row spacing of 40cm.

MAJOR ADVISOR **SIGNATURE OF STUDENT**

HEAD OF THE DEPARTMENT

CURRICULUM VITAE

(a)	Name	:	Pawan Kumar
(b)	Father's name	:	Sh. Jagat singh
(c)	Mother's name	:	Smt. Mayawati
(d)	Date of birth	:	10 September, 1992
(e)	Place of birth	:	Hisar (Haryana)
(f)	Permanent address	:	H. No.- H. No. 319, Ravi Dass Mandir Bawari Gate Bhiwani.
(g)	Mobile	:	8685968876
(h)	Email	:	grewalpawan33@gmail.com

(i) Academic qualifications

Qualifications	University/ Board	Year of passing	Percentage of marks	Division
Matric	CBSE	2008	75	First
Intermediate	CBSE	2010	65.8	First
B.Sc. (Hons.) Agri.	CCSHAU, Hisar	2015	6.57	First
M.Sc. (Vegetable Science)	CCSHAU, Hisar	2017	7.2	First

(j) Co-curricular activities

I hereby, declare that all the information provided in the resume is true to the best of my knowledge.

Dated: 07/09/2017

Place: Hisar **(Pawan Kumar)**

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I Pawan Kumar**, Admn. No. 2015A104M** undertake that I give copy right to the CCS Haryana Agricultural University, Hisar of my thesis entitled **"Effect of seed rate and row spacing on quality seed production of fenugreek (*Trigonella foenum-graecum* L.)"**.

I also undertake the patent if any, arising out of the research work conducted during the programme shall be filed by only with due permission of the competent authority of CCS Haryana Agricultural University, Hisar.

Signature of the student