

Effect of seed rate and nitrogen levels on fodder sorghum (*Sorghum bicolor* (L.) Moench) under custard apple (*Annona squamosa*) based horti-pastoral system



**THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE
REQUIREMENTS FOR THE AWARD TO THE DEGREE OF**

Master of Science (Agriculture)

in

Agroforestry

Submitted by

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CERTIFICATE

To,

The Registrar
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Through: **The Head**
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Dear Sir,

I have great pleasure in forwarding the thesis entitled “**Effect of seed rate and nitrogen levels on fodder sorghum (*Sorghum bicolor* (L.) Moench) under custard apple (*Annona squamosa*) based horti-pastoral system**” submitted by **Mr. Sanjiv Yadav, I.D. No. AGF-15216** in partial fulfillment of the requirements for the degree of **Master of Science (Agriculture)** in **Agroforestry**.

I certify that the work has been carried out under my guidance and the data forming on the basis of this thesis, to the best of our knowledge are original and genuine and no part of the work has been submitted for any other degree or dissertation.

Thanking you

FORWARDED

Your's faithfully

(S. P. Singh)
Supervisor

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ABBREVIATIONS AND SYMBOLS USED

@	:	At the rate of
<i>et al.</i>	:	and others
Cm	:	Centimeter
CD	:	Critical difference
cv.	:	Cultivar
DAP	:	Diammonium Phosphate
DAS	:	Days After Sowing
d.f.	:	Degree of freedom
°C	:	Degree Celsius
Fig.	:	Figure
Gm	:	Gram
Ha	:	Hectare
Kg	:	Kilogram
M	:	Meter
Mg	:	Milligram
Mha	:	million hectares
Mm	:	Millimeter
N	:	Nitrogen
P	:	Phosphorus
K	:	Potassium
<i>viz.</i>	:	Namely
SEm±	:	Standard error mean
i.e.	:	that is
NS	:	Non significant
Max.	:	Maximum
Min.	:	Minimum
SW	:	Standard week
T	:	Tonnes

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INTRODUCTION

Tree component in an agroforestry system increases overall production besides imparting stability to the farming. Among the alternate land use system (fruit based agroforestry system) is readily picked up by the farmer due to cash benefit derived from these system. Horti-pastoral system markedly increases the return per unit of land mainly during early stage of fruit trees. Fruit tree based agroforestry involves intentional and simultaneous association of annual or perennial crops on the same land unit. The relatively short juvenile (pre-production) phase of fruit trees, high market value of product and the contribution of fruits to household dietary needs, fruit-tree-based agroforestry enjoy high popularity among producers worldwide.

Custard apple (*Annona squamosa*) belong to the family Annonaceae, which comprises more than 2000 species of mostly tropical trees and shrubs. The most frequently eaten species is simply referred as the custard apple (*Annona squamosa*). It is native to the tropical America and West Indies. Custard apple are cultivated in the tropics and subtropics of America, New Zealand, Brazil, Argentina and Venezuela. Its mainly cultivated in the states like Andhra Pradesh, Maharashtra, Karnataka, Assam, Bihar, Orrisa and Tamilnadu. In India, an estimated area and production of custard apple is 19,660 ha and 1, 33,050 tonnes, respectively and the productivity is 6.76 tonnes ha⁻¹. The fruits are rich in sugar (23.5%), protein (1.6%), calcium (17mg/100g), phosphorus (47mg/100g) and iron (1.5mg /100 g).

Custard apple is distributed throughout the tropics. The other important features are their wide adaptability to soil and climatic conditions and freedom from pest and diseases. Due to their hardy nature and safe from animal damage, it has been commercialized in many tropical and sub-tropical parts of the world and popular among the local farmers of eastern Uttar Pradesh. Under rainfed condition and in poor fertility Vindhyan region soil, growing of short duration arable crops during rainy (*Kharif*) season is only option for the local farmers.

Sorghum [*Sorghum bicolor* (L) Moench] contains about 10% protein, 3.1% fat, 70.7% carbohydrate, 329 kcal energy, crude fiber 2 g calcium and iron are 25 and 2.4 mg in 100 g of grain, respectively. Sorghum is the fourth most important cereal crop of India, next to rice, wheat and maize in order. Sorghum grown on 8.6 million ha is an important food and fodder crop in the state of Maharashtra, Karnataka, Rajasthan, and Andhra Pradesh (Damame *et al.* 2013) Because of its relative drought tolerance; it is the crop of par excellence for dry regions and areas with uncertain and scanty rainfall. Integrated use of all potential sources of plant nutrients seems to be the only option to maintain soil fertility and crop productivity. Long-term studies on various crops indicated that the balanced use of NPK fertilizer could not maintain the higher yield over years because of emergence of secondary and micronutrient deficiencies and deterioration of soil physical properties. The integrated use of organic material and inorganic nitrogenous fertilizers has received considerable attention in past with a hope of meeting the farmer's economic need as well as maintaining favourable ecological conditions on long-term basis (Kumar *et al.*, 2007)

Among the various fodder crops, sorghum is one of the most important crops widely grown in *kharif* season for fodder in India. The crop has significance over other cultivated fodder crops due to its high production potential wider adaptability, quick growing nature, succulence, palatability excellent fodder quality and it can safely fed to animal at flowering stage. Fertilizer application is one of the principal factor that markedly affect the fodder yield. An adequate supply of nutrient at each growth stage is essential for optimum growth and development of fodder sorghum. Nitrogen is important essential nutrient for physiological, growth and yield point of view (Alloway, 2004), but at the same time establishment of an optimum plant stand is equally important to get maximum yield (Reddy and Reddy, 2010). Therefore, there is a need to evaluate the effect of seed rate and nitrogen on the growth and yield of *kharif* fodder sorghum.

Sorghum is well adapted and grown in a wide range of environment. One of its strongest traits is its great adaptability to tropical and subtropical areas of the world where water availability and soil condition are considered marginal for other crops. Under optimal conditions, sorghum has a high yields potential comparable to other cereal such as rice, maize or wheat (Mohamed, 2011).

Timing and placement of N fertilizer have a major effect on the efficiency of applied N. Nitrogen should be applied to a crop at times that avoids periods of significant loss and provide adequate N when needed. Studies with sorghum have shown that fertilizer knifed-in at planting has increased yields than to broadcast application (Sweeney, 1989; Khosla *et al.*, 2000). Sorghum is an important fodder crop as it can be fed as green fodder or converted to high quality silage for use during the lean period. It occupies the maximum area (2.8 m ha) among different forage crops. Nitrogen should be applied as split application with 50% applied at planting and the remaining 50% applied after the first cut (OMAF, 2002). Most livestock producers, especially dairy farmers, need high-quality forage.

Investigations on the essential factors that determine forage sorghum yield showed favorable responses to nitrogen fertilization (Singh *et al.*, 1988; Iptas and Brohi, 2003). There is a considerable interest in the time and level of nitrogen fertilization required to maximize the total forage yield and at the same time enhance the quality of the forage, however no evidence for optimum time and application of N to harvest higher forage yield during raining season in Vindhyan region. Thus, the main objective of this study is to evaluate the response of different cultivars of forage sorghum to the levels of nitrogen applied.

Keeping these facts in to consideration the present investigation entitled “**Effect of seed rate and nitrogen levels on fodder sorghum under custard apple based horti – pastoral system**” was conducted with following objectives:-

- (1) To study the effect of varied seed rate and nitrogen levels on growth and yield of fodder sorghum under custard apple based horti-pastoral system.
- (2) To study the economics of the treatments.

REVIEW OF LITERATURE

Custard apple is a popular fruit tree of the country, more predominantly in Vindhyan region. Horti-pastoral systems provides an abundant scope to make use of interspaces of fruit trees for cultivating fodder crops without affecting the growth and productivity of fruit trees. Fodder sorghum can be cultivated under rainfed condition during *kharif* season in the interspaces of the fruit trees. Seed rate is important input as it affects plant density and consequently the yield of fodder. Higher seed rates usually results in higher plant density, which increases fodder yield. Nitrogen is a key element in deciding the yield potential of any crop. Therefore, an effort was made to select optimum seed rate and nitrogen level of fodder sorghum under horti-pastoral system. Thus, an attempt has been made in this chapter to review the literature available on fodder sorghum and other related crops in the country with respect to various aspects of horti-pastoral system, seed rate and nitrogen levels, interaction between fruit trees and crops and their effects are presented below:

2.1 Effect of seed rate

2.1.1 Growth parameters

Verma *et al.* (2005) found that seed rate of 7.5 kg ha⁻¹ recorded significantly higher leaf: stem ratio than 5 kg while at par with 10 kg ha⁻¹ seed rate of fodder sorghum.

Ahmad (2007) reported that sorghum sown using single row hand drill @ 75 kg ha⁻¹ 30 cm apart in rows produced highest plant height (175.7 cm) and number of leaves (13.33) plant⁻¹.

Ayub *et al.* (2007) revealed that seed rate of 20 kg ha⁻¹ significantly increased the plant density, plant height, dry matter of pearl millet but decreased the stem diameter.

Malik *et al.* (2007) reported that seed rate of 75 kg ha⁻¹ with row spacing of 15 cm resulted in increased plant height and leaf area of sorghum.

Ali *et al.* (2014) the results showed a reduction in leaf to stem ratio with the increase of seed rate (71, 107 and 143 kg ha⁻¹) of forage maize.

Somashekar *et al.* (2015) found that significantly higher plant height of sorghum was recorded with seed rate of 7.5 kg ha⁻¹ compared to that with seed rate of 5 kg ha⁻¹ and 10 kg ha⁻¹.

Prajapati *et al.* (2017) found that stem diameter of sorghum significantly decreased with increased seed rate. The maximum (1.19 cm) and minimum (0.94 cm) stem diameter were recorded at seed rate of 30 kg ha⁻¹ and 45 kg ha⁻¹, respectively.

2.1.2 Fodder yield

Ayub *et al.* (1999) found that significantly highest maize green fodder yield was produced with seed rate of 125 kg ha⁻¹. The seed rate of 125 kg ha⁻¹ give 7.9% and 18.3% more green fodder yield than 100 kg ha⁻¹ and 75 kg ha⁻¹ seed rate, respectively.

Gonzalez *et al.* (2000) revealed that highest green fodder and dry matter yields were registered with 75 kg ha⁻¹ seed rate of sorghum.

Malik *et al.* (2007) found that the highest seed rate of sorghum (75 kg ha⁻¹) resulted in highest fodder yield (57.36 t ha⁻¹).

Carpici *et al.* (2010) concluded from his experiment that maximum green fodder and dry matter yields of forage maize were recorded with seed rate of 143 kg ha⁻¹.

Osman *et al.* (2010) found that leaf: stem ratio of sorghum was not significantly influenced by seed rate. Significant and consistent increase in green fodder yield was noted with increase in seed rate. Seed rate of 40 kg ha⁻¹ increased dry fodder yield by 12.78 and 21.30% over 35 and 30 kg ha⁻¹.

Singh *et al.* (2012) found that sorghum grown with seed rate @ 45 kg ha⁻¹ and 40 kg ha⁻¹ has produced statistically similar dry matter, both produced significantly superior dry matter than 35 and 30 kg ha⁻¹.

Somashekar *et al.* (2015) observed that sorghum green fodder yield was significantly influenced by seed rates. Seed rate of 7.5 kg ha⁻¹ recorded significantly higher green fodder yield than that of 5 kg ha⁻¹ but was at par with 10 kg ha⁻¹.

Prajapati *et al.* (2017) found that seed rate of 40 kg ha⁻¹ has produced higher fodder sorghum yield.

2.1.3 Residual nutrient status of the Soil

Somashekar *et al.* (2015) found that seed rate of 5 kg ha⁻¹ recorded significantly higher available nitrogen content in soil (226.41 kg ha⁻¹) as compared to 7.5 and 10 kg ha⁻¹. Seed rate of 7.5 kg ha⁻¹ recorded significantly higher available phosphorus (25.46 kg ha⁻¹) and potassium (115.13 kg ha⁻¹) than 5 kg ha⁻¹, while recorded at par values with 10 kg ha⁻¹ after final harvest of sorghum.

Prajapati *et al.* (2017) revealed that 30 kg ha⁻¹ seed rate recorded maximum (335.46 kg ha⁻¹) potassium, compared to remaining seed rates (35, 40, and 45 kg ha⁻¹). However, seed rate failed to record any significant change in available nitrogen and phosphorus in soil after the harvest of fodder sorghum.

2.1.4 Economics

Ausufali *et al.* (2007) observed that seed rate of 125 kg ha⁻¹ recorded higher net income (Rs.12723) and benefit cost ratio (2.89) in rice bean, found at par to seed rate of 150 kg ha⁻¹.

Somashekar *et al.* (2015) found that higher gross returns (Rs.59911 ha⁻¹), net returns (Rs.35018 ha⁻¹) and B: C ratio (2.40) was obtained with the seed rate of 7.5 kg ha⁻¹ as compared to that with seed rate of 10 and 5 kg ha ha⁻¹ in sorghum.

Prajapati *et al.* (2017) reported that percent increase in net returns due to seed rate of 45 kg ha⁻¹ was 24.6%, 10.3% and 20.6% compared to seed rate 30, 35 and 40 kg ha⁻¹, respectively. Seed rate 45 kg ha⁻¹ recorded 18.0%, 4.3% and 4.1% higher B: C ratio over 30, 35 and 40 kg ha⁻¹, respectively.

2.2 Effect of nitrogen

Nitrogen plays an important role in plant metabolism by virtue of being an essential constituent of diverse type of metabolically active compounds like amino acids, proteins, enzymes, co-enzymes and alkaloids. Nitrogen is an important nutrient for increasing fodder production and nutritive value of sorghum (Desale *et al.*, 1999).

2.2.1 Growth characters

Patel (1998) conducted a field trial at Durg (C.G.) using 0, 25, 50 and 75 kg N ha⁻¹ with cultivar MP Chari of forage sorghum under multicut management. Plant height and number of leaves plant⁻¹ increased significantly with each increment in the nitrogen level from 0 to 75 kg N ha⁻¹.

Akbari *et al.* (2000) reported that application of 50 kg N ha⁻¹ gave the highest dry matter yield of fodder sorghum.

Kazemi *et al.* (2000) revealed that highest dry matter yield of fodder sorghum was produced with application of 200 kg N ha⁻¹, and it was at par with 150 kg N ha⁻¹.

Ram and Singh (2001) found that application of nitrogen @ 80 kg ha⁻¹ significantly increased dry matter yields of sorghum compared to control and 40 kg ha⁻¹.

Ayub *et al.* (2002) conducted experiment during *kharif* season at Faisalabad and found that significant increase in the plant height of fodder sorghum with each incremental dose of nitrogen 0 to 180 kg ha⁻¹. Ram and Singh (2001) revealed that tallest sorghum plants were produced with 80 kg ha⁻¹.

Girija Devi (2002) found that significantly higher dry matter yields of maize was produced with 125 kg N ha⁻¹ over 0, 25 or 50 kg N ha⁻¹. However, the yield obtained with 125 kg N ha⁻¹ was statistically similar with that of 75 and 100 kg N ha⁻¹.

Kumar *et al.* (2004) conducted experiment with variety Haryana Chari – 136 of fodder sorghum and recorded statistically similar leaf to stem ratio with the application of 40 and 80 kg N ha⁻¹.

Patidar and Mali (2004) reported that significantly highest chlorophyll content of sorghum was obtained with 120 kg N ha⁻¹.

Agarwal *et al.* (2005) executed a field trial on a clay loam soil at Jabalpur (MP) during *kharif* season and reported that the number of functional leaves increased significantly with increasing levels of nitrogen from 0 to 150 kg ha⁻¹.

Dhar *et al.* (2005) conducted an experiment with HD-15 variety of fodder sorghum and found that plant height was significantly superior with application of 120 kg N ha⁻¹, while number of green leaves significantly improved up to 80 kg ha⁻¹.

Kaushik and Shaktawat (2005) stated that nitrogen applied @ 120 kg ha⁻¹ recorded higher dry matter plant⁻¹ in sorghum during rainy season over other N levels (0, 40 and 80 kg ha⁻¹).

Singh *et al.* (2005) revealed that multicut sorghum grown during *kharif* season with 100 kg N ha⁻¹ recorded significantly highest plant height.

Hani *et al.* (2006) found that number of leaves per plant in fodder sorghum was not significantly affected by nitrogen levels. Application of 80 kg N ha⁻¹ produced significantly higher LAI as compared to 40 kg N ha⁻¹ and control.

Khaleduzzaman *et al.* (2007) reported that higher dry matter yield of Napier grass was recorded with 160 kg N ha⁻¹.

Gupta *et al.* (2008) found that sorghum dry matter yield increased to the extent of 19.4, 25.1 and 41.2% with the application of 40, 80 and 120 kg N ha⁻¹ over control, respectively.

Sharifi and Teghizadeh (2009) reported that plant height increased with increasing levels of nitrogen application and maximum plant height (204.6 cm) was recorded with 240 kg N ha⁻¹. Ayub *et al.* (2011) found that the plant height and dry matter yield of guar crop was increased significantly with increase in nitrogen levels from 0 to 45 kg ha⁻¹. The highest plant height and dry matter was recorded with 45 kg N ha⁻¹.

Afzal *et al.* (2012) found significant difference with three cuttings in forage sorghum. Maximum dry weight (74.6, 115.0 and 93.8 g plant⁻¹) was observed with 240 kg N ha⁻¹ in first, second and third cutting, respectively compare to control, 120, and 180 kg N ha⁻¹.

Singh *et al.* (2012) reported that application of 90 kg N ha⁻¹ has recorded significantly higher plant height (239.2 cm) and number of tillers (31.7) of pearl millet compared to control treatment.

Mishra *et al.* (2013) showed that maximum plant height of sorghum was obtained by application of 225 kg N ha⁻¹.

Patil *et al.* (2014) revealed that significantly maximum number of leaves plant⁻¹ of forage sorghum at harvest was recorded with 125% N of RDF ha⁻¹ than the other levels of nitrogen except with 100% N of RDF ha⁻¹.

Prasad *et al.* (2014) studied that application of 60 kg N ha⁻¹ recorded significantly higher plant height (159.86 cm), number of tillers (2.16) and dry matter accumulation (82.43 g plant⁻¹) respectively, compared to control in pearl millet.

Nirmal *et al.* (2016) revealed that the dry matter accumulation plant⁻¹ recorded with application of 125% N of RDF ha⁻¹ of forage sorghum was significantly higher than other levels of nitrogen application except 100% N of RDF ha⁻¹.

2.2.2 Green fodder yield

Malik *et al.* (1996) revealed that application of 50 kg ha⁻¹ nitrogen significantly increased the green fodder yield of sorghum.

Pankhaniya *et al.* (1997) reported that the green fodder yield of sorghum was significantly increased with each increment in N level from 0 to 60 kg ha⁻¹.

Desale *et al.* (1999) at Rahuri during *kharif* season found that the increasing levels of nitrogen from 0 to 120 kg ha⁻¹ progressively increased the green fodder yield and the highest value noted by 120 kg N ha⁻¹.

Gadhethariya *et al.* (2000) observed that multicut green forage sorghum has produced greater fodder yield with 120 kg N ha⁻¹.

Ram and Singh (2001) revealed that nitrogen @ 80 kg ha⁻¹ significantly increased green forage yields of sorghum compared to control and 40 kg ha⁻¹.

Ayub *et al.* (2002) reported that application of nitrogen in fodder sorghum significantly increased green fodder yield. Nitrogen @ 180 kg ha⁻¹ produced highest green fodder yield and was statistically similar to 120 kg ha⁻¹.

Bhilare *et al.* (2002) reported that increasing levels of nitrogen from 30 to 120 kg ha⁻¹ progressively increased the green fodder yield of sorghum, maximum yield was

obtained with 120 kg N ha⁻¹ in three equal splits *i.e.*, 1/3rd as basal + 1/3rd at 30 DAS + 1/3rd after first cut.

Rathod *et al.* (2002) conducted experiment during *kharif* season and stated that green fodder yield of sorghum increased with increasing levels of nitrogen from 80 to 120 kg ha⁻¹.

Agarwal *et al.* (2005) found that the highest green fodder sorghum yields were obtained with level of 150 kg nitrogen ha⁻¹ compared to control.

Dhar *et al.* (2005) conducted an experiment on a clay loam soil during *kharif* season and reported a significant increase in green fodder yield of sorghum from 40 to 120 kg N ha⁻¹.

Verma *et al.* (2005) reported that nitrogen application of 120 kg ha⁻¹ increased the green fodder yield of fodder sorghum by 35.8% over control.

Ayub *et al.* (2007) found that significantly highest green fodder yield of pearl millet was produced by 150 kg N ha⁻¹.

Manjunath *et al.* (2013) observed that the green fodder sorghum yield in all cuts was significantly increased with successive increase in nitrogen levels from 120 to 300 kg ha⁻¹. The fodder yield obtained with 300 kg N ha⁻¹ was 38.7, 24.7 and 11.6% higher than 120, 180 and 240 kg N ha⁻¹, respectively.

2.2.3 Dry fodder yield

Pankhaniya *et al.* (1997) found that the dry matter yield of sorghum cultivar GFS-4 was highest with the application of 60 kg N ha⁻¹.

Dry matter yield of sorghum was significantly increased at each increased rate of nitrogen (0, 50, 100, 150 kg ha⁻¹). The maximum dry matter yield was recorded @ 150 kg N ha⁻¹ and minimum yield was observed with no nitrogen (Ahmad, 1999).

Bhilare *et al.* (2002) conducted an experiment on a clayey soil during *kharif* season at Rahuri (Maharashtra) and reported that an increase in dry fodder yield of sorghum was obtained with 120 kg ha⁻¹ in three equal splits *i.e.*, 1/3rd at basal + 1/3rd at 30 DAS + 1/3rd after first cut.

Rathod *et al.* (2002) reported that dry fodder yield of fodder sorghum increased with increasing levels of nitrogen 80 to 120 kg ha⁻¹.

Patel and Rajagopal (2003) found that sole sorghum with 100 and 75 kg N ha⁻¹, being at par, recorded significantly dry forage (8.81 and 8.41 t ha⁻¹) yields than sole sorghum with 50 kg N ha⁻¹.

Dudhat *et al.* (2004) found that application of 80 kg N ha⁻¹ produced significantly higher dry fodder yields of fodder maize over 0 and 40 kg N ha⁻¹.

Sheikh (2004) revealed that highest dry fodder yield of guar was obtained with 120 kg N ha⁻¹ compared to their control lower levels.

Sharma and Verma (2005) reported that dry matter yield of fodder oats significantly increased with the increasing levels of nitrogen from 50 to 150 kg ha⁻¹.

Cerny *et al.* (2012) observed that dry matter yield of fodder maize linearly increased with increase in mineral fertilizer N up to 120 kg ha⁻¹.

Saini *et al.* (2012) reported that application of 125% nitrogen of the recommended dose produced the highest dry matter yield of fodder sorghum which was 14.3 and 5.1% higher than 75 and 100% of the recommended dose.

Singh *et al.* (2012) indicated that sorghum dry fodder yield showed consistent increase with increase in nitrogen rates from 40 to 100 kg ha⁻¹. 80 kg N ha⁻¹ increased dry fodder yield by 13.37 and 23.20% over 60 and 40 kg N ha⁻¹, respectively.

2.3 Soil fertility

Srinivasaraju *et al.* (1997) reported a decreased trend in nitrogen fertility status of soil due to increasing level of nitrogen in comparison to initial fertility status.

Verma *et al.* (1999) found that residual soil fertility is significantly influenced by various nitrogen levels (120, 180, 240, N kg ha⁻¹) applied to the fodder maize. Tripathi and Hazra (2002) observed that soil available nitrogen status after the harvest of fodder maize was higher with 90 kg N ha⁻¹.

Abou-Amer (2007) found that the maximum soil phosphorus was observed with treatment 100-30 kg NP ha⁻¹ after harvest of fodder sorghum and next best treatment was 100-0 kg NP ha⁻¹.

Singh and Dubey (2007) revealed that application of 80 kg N ha⁻¹ in oats significantly increased the organic carbon, available N, P and K after harvest of oats.

Sharma (2009) observed significantly higher organic carbon (0.27%) and available N (144.3 kg ha⁻¹) under highest dose of N (150 kg ha⁻¹) in oats. The improvement in organic carbon and available N due to application of 150 kg N ha⁻¹ was to the tune of 14.8 and 12.4%, respectively, over control.

2.4 Economics

Karwasara and Dahiya (1997) reported that on a sandy loam soil during *kharif* season at Hisar (Haryana), application of 120 kg N ha⁻¹ gave the maximum net return in fodder sorghum.

Ram and Singh (2001) revealed that application of N @ 80 kg ha⁻¹ recorded significantly higher gross income (Rs.17352 Rs ha⁻¹), net income (Rs.11050 ha⁻¹) and net return per rupee invested (1.74) of fodder sorghum compared with the control and 40 kg N ha⁻¹.

Dudhat *et al.* (2004) showed that application of 80 kg N ha⁻¹ secured the highest additional net return of Rs. 1853 ha⁻¹ so far as cost benefit ratio is concerned; 60 kg N ha⁻¹ was superior to the treatment of 80 kg N ha⁻¹ in forage maize which had recorded cost benefit ratio of 1:2.82.

Kumar *et al.* (2004) conducted experiment with fodder sorghum during *kharif* season and reported that application of nitrogen @ 80 kg ha⁻¹ resulted in maximum benefit: cost ratio of 2.21 compared to other treatments.

Singh *et al.* (2005) reported that application of 80 kg N ha⁻¹ recorded significantly higher gross return (Rs.65483 ha⁻¹) and net return (Rs.60023 ha⁻¹) of sorghum over control and 40 kg N ha⁻¹ while found at par with higher level (120 kg N ha⁻¹) during both years of experiment.

Reddy and Bhanumurthy (2010) reported that forage maize grown for green fodder; dry fodder and grain purpose gave significantly higher net returns (Rs.24.509 ha⁻¹) by the application of 240 kg N ha⁻¹ in three splits (0, 30 and 70 DAS).

2.6 Effect of horti-pastoral system on arable crops

2.6.1 Growth parameters

Ram and Kumar (2009) conducted an experiment at Indian Grassland and Fodder Research Institute, Jhansi on sandy loam soil in 6-years old established custard apple (*Annona squamosa* L.) orchard and observed that the plant height and number of branches plant⁻¹ of legumes (*S. hamata* with *baffale* grass) significantly increased with application of phosphorus and potash @ 60 and 45 kg ha⁻¹ than lower levels and the control.

Shweta *et al.* (2015) found that the Intercropping interact positively to guava tree as it improved the height (16.21%, 17.99% and 22.72%) for cowpea, guar and mungbean respectively. It is assumed that the adding of fertilizers and irrigation to intercrops might have ameliorated the status of nutrient and moisture in orchard which inturn enhanced tree growth. Jose *et al.* (2004) also reported that deeper roots of trees act as a safety net by capturing nutrients that leach below the rooting zone of the crops and recycle them back into the system by tree component. Other studies revealed that yield are influenced by edaphic factors (Deen *et al.*, 1998 and Padmapriya and Chezhiyan, 2009). Cowpea was proved to be a slightly better intercrop as compared to guar and munbean as for as tree canopy concern. Plant height of all the inter crops increased progressively over time. Cow pea has maximum plant height from starting to harvest (17.12 cm to 117.4 cm).

2.6.2 Yield and yield attributes

Kumar and Kumar (2002) observed the effects of N rates (0, 40, 80 and 120 kg ha⁻¹) and ber (*Ziziphus mauritiana*) cv. Gola pruning (0-30, 0-60 and 0-90 cm) on the growth and yield of pearl millet (*Pennisetum glaucum*) planted under ber were determined in a field experiment conducted in Jhansi during 1999-2001. Better growth and yield was recorded during the first than the second year. Plant height and crop yield

were highest in pearl millet planted under heavily pruned ber. Pearl millet yield was highest with 120 kg N ha⁻¹.

Kumar *et al.* (2003) observed the performance of maize and lentil crops grown in four land use systems viz. agri-silviculture (mulberry + maize-lentil), agri-horticulture (peach + maize-lentil), agri-horti-silviculture (peach + mulberry + maize-lentil) vis a vis sole cropping (maize-lentil) in the mid hills of Western Himalayas revealed that agri-silviculture system gave highest (228.50 qt ha⁻¹ year⁻¹) biomass productivity followed by agri-horti-silviculture (207.29 qt ha⁻¹ year⁻¹), agri-horticulture (185.15 qt ha⁻¹ year⁻¹) and sole cropping (174.70 qt ha⁻¹ year⁻¹) system.

Singh *et al.* (2007) evaluated six cropping systems of green fodder i.e. maize + cowpea-oat-maize + cowpea; maize + cowpea-berseem-maize + cowpea; jowar-berseem-maize + cowpea; jowar-oat-maize + cowpea; pearl millet + cowpea-oat- pearl millet + cowpea and pearl millet + cowpea-berseem-pearl millet + cowpea, were tested under agri-horti system with guava tree planted at 8 x 6 m. The green fodder crops pearl millet + cowpea gave maximum average yield (374.5 q ha⁻¹). During rainy season from the interspaces of guava at 75% plant stand followed by green fodder crops of jowar (336.0 q ha⁻¹). The maize + cowpea fodder crops gave lowest average yield of green fodder (249.5 q ha⁻¹)

Das *et al.* (2011) studied the aonla-based agri-horticultural systems. The results indicated that the production of fruits significantly increased due to intercrops and it was maximum in aonla in association with turmeric (13.30 tonnes ha⁻¹) followed by arbi (11.71 tonnes ha⁻¹). On the other hand, reduction in yield of intercrops was 7.5–12.0% for turmeric, 12.2–19.3% for ginger and 15.7–25.3% for arbi compared to the yield in open area without trees.

Avinash *et al.* (2013) evaluated the mango based agri-horticultural models (AHM) viz. mango + cowpea–toria, mango + cluster bean/okra– toria, mango + sesame–toria, mango + black gram–toria and mango + pigeon pea in addition to sole mango plantation .The maximum cowpea equivalent yield was harvested from cowpea (1.84 t ha⁻¹) followed by okra (1.21t ha⁻¹), black gram (1.11t ha⁻¹), sesame (0.68 t ha⁻¹) and minimum with pigeonpea (0.58t ha⁻¹). The crop yield reduction among the mango based AHM was observed from third year to tenth year. Agri -horti system were effective in improving fruit yields of the mango. The maximum fruit yield of mango

(7.02 t ha⁻¹) was harvested with cowpea–toria crop rotation followed by black gram–toria (6.59 t ha⁻¹) and minimum fruit yield (5.76 t ha⁻¹) realized with sole mango tree.

2.7 Interaction between crops and tree components

Wannawong *et al.* (1999) concluded that intercropping trees with green gram, early supplementary and complementary relationships between some system components can imply synergistic financial gains. Although these biological interactions turn competitive over time, in this case, the gains should be sufficient to make early adopter consider the agroforestry system financially preferable to traditional mono crops.

2.7.1 Competition for light

Investigations on light interception and competition in agroforestry system are generally scarce. An additional problem is the difficulty to compare the available results because of the difference in methodologies used in the investigation.

2.7.2 Root and water competition

Singh *et al.* (1998) conducted an experiment and reported that in an alley-cropping trial of *Leucaena* with cowpea, castor, and sorghum under semiarid condition in India, competition for water appeared more important than shading effect.

Jonsson *et al.* (1999) reported that microclimate amelioration and enhanced soil fertility may exceed the potentially detrimental influence of shade.

MATERIAL AND METHODS

The present experimentation entitled “**Effect of seed rate and nitrogen levels on fodder sorghum under custard apple (*Annona squamosa* L.) based horti-pastoral system**” was carried out during *kharif* season of 2016-17 at agriculture research farm. The edaphic and climatic condition under which the experimental crop was raised and materials and techniques employed in conducting the experiment are described in this chapter.

3.1 Experimental site

The experiment was carried out at the Agricultural Research Farm, Rajiv Gandhi South Campus, Brakachha, Banaras Hindu University, Mirzapur situated at Vindhyan region of district Mirzapur (25° 10’ latitude, 82° 37’ longitude and at an altitude of 427 meters above mean sea level) occupying over an area of more than 1000 ha where variety of crops like agricultural, horticultural, medicinal and aromatic plants are grown. Vindhyan soil comes under rainfed and invariably poor fertility status. This region comes under agro-climatic zone III A (semi-arid eastern plain zone –III A).

3.2 Climate and weather

The climate of Barkachha is typically semi-arid to sub humid, characterized by extremes of temperature both in summer and winter with low rainfall and moderate humidity. Mean weather data of 10 year (2006 to 2016) of the region in presented in Table 3.1 and graphically presented in Fig. 3.1.

Table. 3.1. The 10 year mean weather data during 2006-2016 is presented in the table 3.2

Month	Rainfall (mm)	Temperature (°C)		Relative humidity (%)		Sunshine (hours)	Evaporation (mm)
		Max.	Min.	Max.	Min.		
January	1.9	19.70	7.04	86.23	44.67	6.27	1.73
February	1.6	26.95	11.15	84.58	45.20	8.35	2.42
March	1.08	33.10	15.83	73.46	28.40	8.39	4.64
April	0.44	35.96	20.42	57.09	23.5	9.38	5.10
May	3.27	39.85	26.65	64.86	27.50	9.18	8.64
June	53.46	46.08	27.73	72.8	50.28	7.08	7.72
July	57.18	32.14	27.18	84.34	71.24	4.72	3.41
August	74.23	31.18	26.73	88.5	75.10	5.35	3.27
September	76.51	30.9	26.50	88.36	73.62	6.26	3.12
October	0.98	31.67	20.71	85.16	45.82	8.34	3.0
November	0.23	28.41	14.67	91.31	40.65	8.20	2.5
December	0.33	21.10	9.06	93.82	56.47	6.48	1.53

Source: All India Co-ordinated Research Project on Dryland Agriculture (BHU).

The normal period for the onset of monsoon in this region is the third week of June and it lasts up to end of September or sometimes extends to the first week of October. Winter showers are often experienced in between the month of December to mid of February.

Weather data during the crop period has been presented in Table 3.2. During the crop season total rainfall received was 179.87 mm. Out of total rainfall, more than 88 per cent received between 32 to 35 standard meteorological weeks (SMW). Data showed that the weekly mean maximum temperature ranged from 30.2 to 35.1°C with

an average of 33.6°C during 2016. The weekly mean minimum temperature ranged from 20.26 to 26.05°C with an average of 25.0. The relative humidity varied between 46.3 per cent and 96.6 per cent.

Figure 3.1: The 10 year mean weather data during 2006-2016 of the area is presented in the figure 3. 1

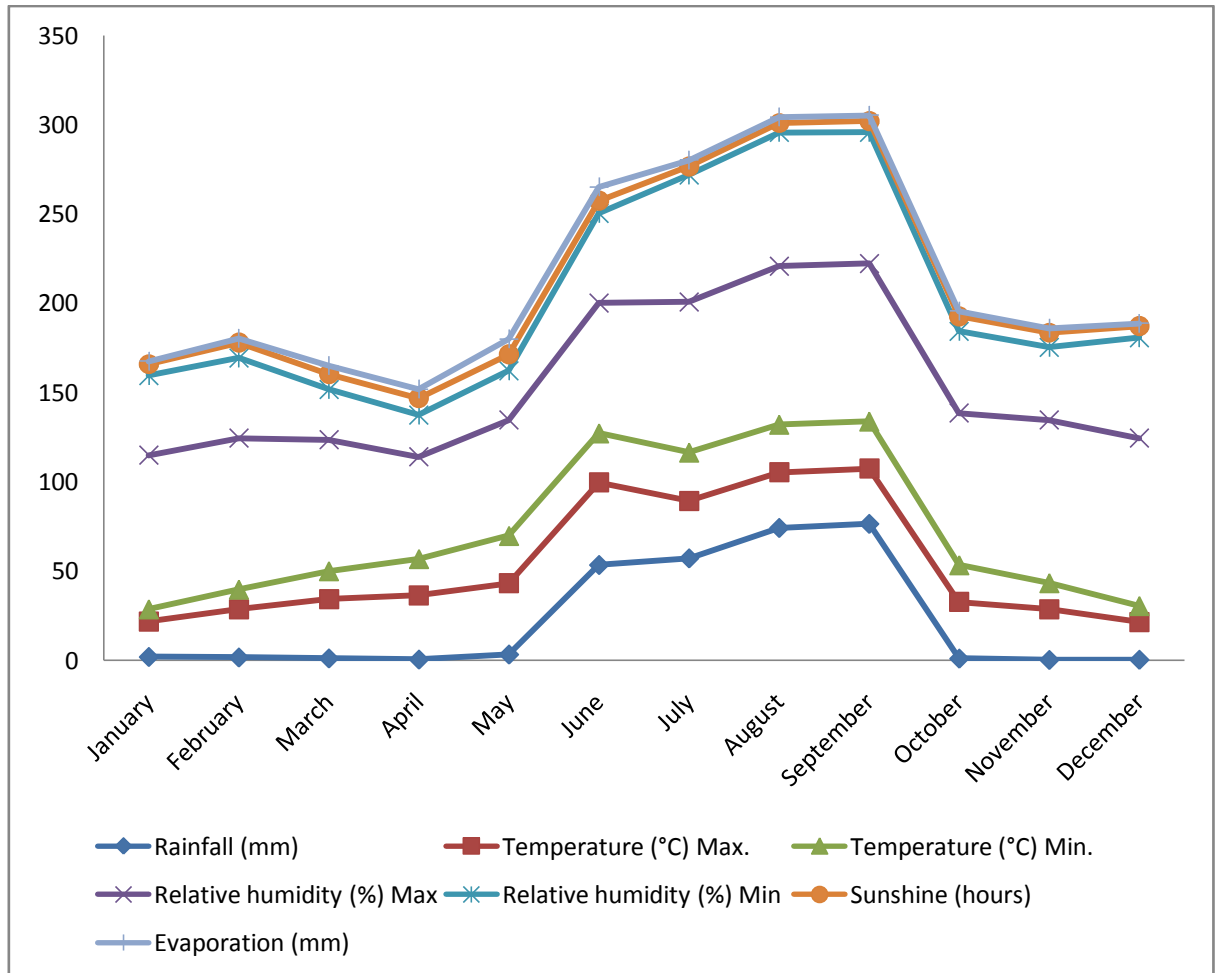


Table: 3.2: Mean week-wise meteorological data during crop season *kharif*, (2016)

Standard Week No.	Month	Date	Rainfall (mm)	Temperature (°C)		Relative Humidity (%)
				Max.	Min.	
36	September	03-09	18.1	35.12	26.05	95.50
37		10-16	29.1	34.35	26.23	94.14
38		17-23	37.9	33.34	26.21	96.57
39		24-30	76.7	34.92	25.02	92.57
40		01-07	18.07	33.34	25.67	82.10
41	October	08-14	00	34.58	25.91	70.56
42		15-21	00	34.95	25.30	69.35
43		22-28	00	32.23	25.35	65.62
44		29-04	00	32.65	24.40	59.36
45	November	05-11	00	30.21	20.26	46.32
Total			179.87			
Mean				33.56	27.60	77.20

3.3 Soil characteristics of experimental field

The soil of the experimental field was sandy clay loam in texture with poor drainage. It was acidic in reaction, low in available nitrogen as well as phosphorus and medium in available potassium. Composite soil samples prior to the experiment were collected to determine mechanical composition and physico-chemical properties of the soil and the data are presented in Table 3.3.

Table.3.3. Physico-chemical properties of the experimental soil

Soil properties	Value	Method employed
a. Physical		
Coarse sand (%)	10.34	International Pipette Method (Piper, 1966)
Fine sand (%)	48.31	
Silt (%)	19.22	
Clay (%)	21.58	
Textural class	Sandy clay loam (Typic Ustochrept)	Textural triangle (Black, <i>et al.</i> 1965)
Bulk density (Mg m^{-3})	1.43	
Particle density (Mg m^{-3})	2.47	
b. Chemical		
pH (1:2.5, soil and water suspension)	5.4	Glass electrode method digital. PH meter (Jackson, 1973)
Electrical conductivity (d Sm^{-1} at 25°C)	0.30	Systronics electrical conductivity meter (Chopra and Kanwar, 1976)
Organic carbon (%)	0.27	Walkley and Black's rapid titration method (Piper, 1966)
Available nitrogen (kg ha^{-1})	183.67	Alkaline permanganate method (Subbiah and Asija, 1956)
Available phosphorus (kg ha^{-1})	16.76	0.5 M NaHCO_3 extractable (Olsens, <i>et al.</i> 1954)
Available potassium (kg ha^{-1})	183.25	Ammonium acetate extractable flame photometer method (Jackson, 1973)

3.4 Cropping history of the experimental field

The crop sequences followed in the experimental field during the past five years have been presented in Table 3.4. The cropping history of the experimental site clearly indicates that the field was ideally suitable for the experiment. Pulses were taken in the crop sequence thus, the fertility set up has not been disturbed.

Table. 3.4. Cropping history of the experimental field.

Year	Kharif	Rabi
2011-12	Pearl millet	Mustard
2012-13	Mungbean	Fallow
2013-14	Mungbean	Fallow
2014-15	Mungbean	Fallow
2015-16	Black gram	Fallow
2016-17	Fodder sorghum*	-

* Experimental Crop

3.5 Experimental details

Experiment was laid out in a randomized complete block design with three replications during rainy (*kharif*) season of 2016 in nine year old custard apple which were planted in August, 2006 at a spacing of 5×5 m². Sorghum was sown as intercrop in the alleys of custard apple tree. Each replication was divided into 12 equal plots and treatment was randomly allocated within the block for each replication. (Table 3.5)

Experimental design	Randomized block design
No. of treatments	12
No. of replications	3
Total plots	12×3 = 36
Gross plot size	4.50m × 3.9m
Net plot size	4m × 3.4m
field border	1 m
Plot border	0.5m
Spacing	30x5 cm
Variety	MFSH-4 (RASEELA)
Season	<i>Kharif</i>

Table. 3.5: The treatments and their symbols used in this experiment are *kharif* 2016 as under.

S.No	Treatment	Symbol
1	30 kg ha ⁻¹ seed + control	S ₁ N ₁
2	30 kg ha ⁻¹ seed + 40 kg ha ⁻¹ nitrogen	S ₁ N ₂
3	30 kg ha ⁻¹ seed + 80 kg ha ⁻¹ nitrogen	S ₁ N ₃
4	30 kg ha ⁻¹ seed + 120 kg ha ⁻¹ nitrogen	S ₁ N ₄
5	40 kg ha ⁻¹ seed + control	S ₂ N ₁
6	40 kg ha ⁻¹ seed + 40 kg ha ⁻¹ nitrogen	S ₂ N ₂
7	40 kg ha ⁻¹ seed + 80 kg ha ⁻¹ nitrogen	S ₂ N ₃
8	40 kg ha ⁻¹ seed + 120 kg ha ⁻¹ nitrogen	S ₂ N ₄
9	50 kg ha ⁻¹ seed + control	S ₃ N ₁
10	50 kg ha ⁻¹ seed + 40 kg ha ⁻¹ nitrogen	S ₃ N ₂
11	50 kg ha ⁻¹ seed + 80 kg ha ⁻¹ nitrogen	S ₃ N ₃
12	50 kg ha ⁻¹ seed + 120 kg ha ⁻¹ nitrogen	S ₃ N ₄

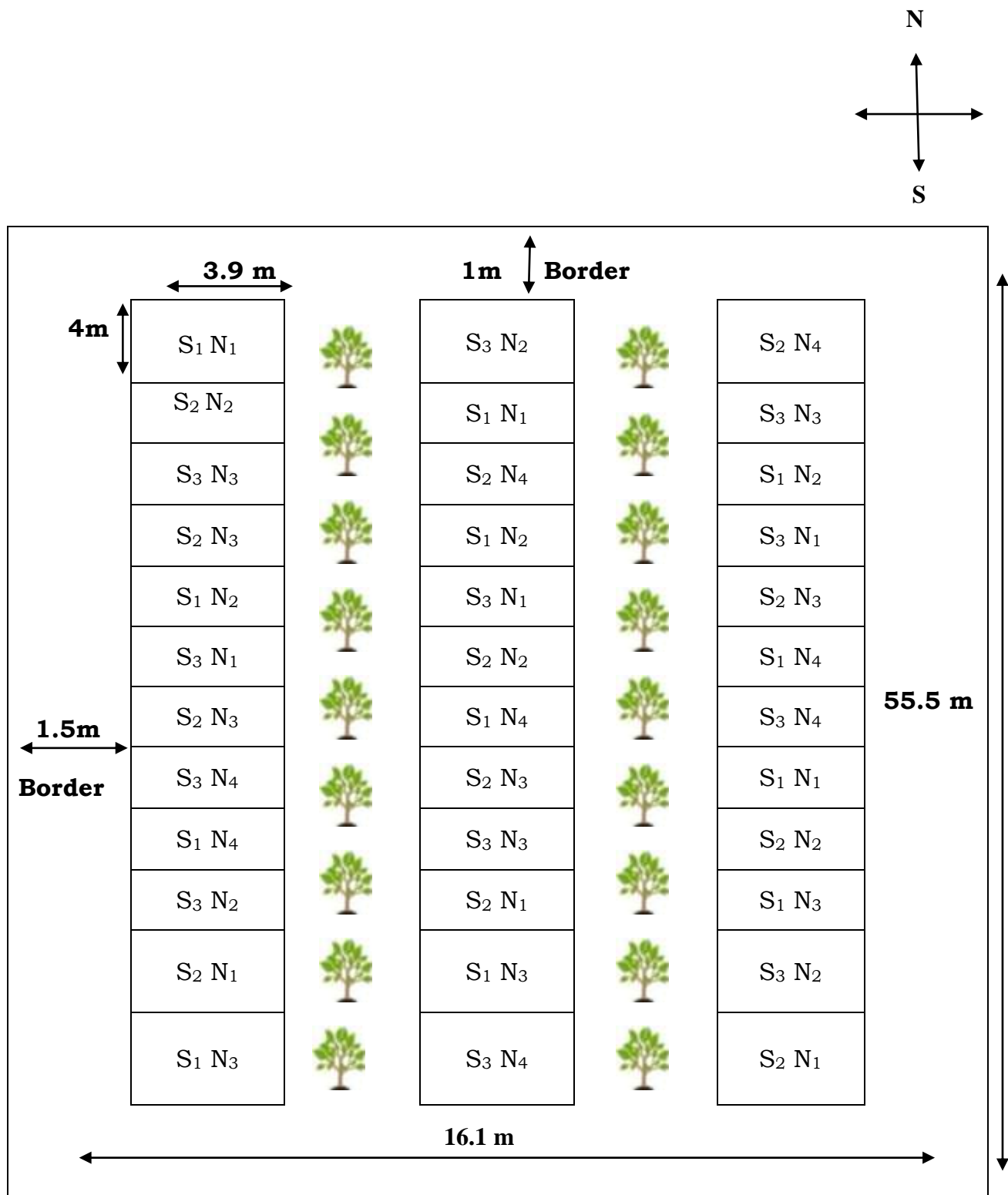


Fig. 3.2. Layout plan of the experimental field

3.6 Experimental crop and variety

Fodder sorghum (*Sorghum bicolor* (L) Moench) variety MFSH- 4 (RASEELA) chosen as test crop under custard apple based horti-pastoral system. This is a recommended hybrid variety for cultivation of fodder sorghum in *kharif* season, matures in 60 days and 1000 grain weight is 20-30 g. The grain is medium large and yield potential is 40-50 q ha⁻¹.

3.7 Agronomic practices

The details of cultural operations done starting from field preparation to harvesting of the crop are given in Table 3.6.

Table 3.6. Schedule of field operations.

S. No.	Operation	Date
(A).	Pre-sowing operations	
1.	Land preparation	
	(i) First ploughing	03.09.2016
	(ii) Second ploughing	04.09.2016
2.	Layout	05.09.2016
(B).	Sowing operations	
1.	Fertilizer application	06.9.2016
2.	Sowing	06.09.2016
(C).	Post-sowing operations	
1.	Thinning	21.09.2016
2.	Weeding and hoeing	26.09.2016
3.	Fertilizer top dressing of nitrogen	06.10.2016
4.	Harvesting	07.11.2016
(D)	Harvesting of fruits	30.11.2016

3.7.1 Land preparation

At workable condition, field was ploughed with the help of disc plough and harrowing was done followed by planking. Thereafter, the experiment was laid out as per plan and design. (Figure 3.2)

3.7.2 Manure and fertilizer application

Fertilizer application was done as per the treatments. Half the dose of nitrogen and full of phosphorus and potash was applied as basal at sowing and remaining half nitrogen was top dressed one month after sowing followed by irrigation. Sources used were urea, di ammonium phosphate (DAP) and muriate of potash (MOP). Nitrogen was applied as per treatments while phosphorous @ 60 kg ha⁻¹ and potassium @ 40 kg ha⁻¹.

3.7.3 Seed and sowing

Seeds were sown after seed treatment with Thiram. The seeds were sown manually by *kudal* at a row distance of 30 cm apart. Seed rate was used 30, 40, and 50 kg ha⁻¹ as per treatment.

3.7.4 Intercultural operation

One hand weeding was done manually by *khurpi* at 20 days after sowing to control the weeds.

3.7.5 Harvesting

Harvesting was done on 7th Nov, 2016. The crop from the border row of each plot was harvested first. The crop in the net plot area was harvested close to ground, separately bundled and weighed as green fodder yield. Then the green fodder was dried until constant weight obtained and dry fodder yield was recorded.

3.8 Biometric observations

Five plants from each plot were randomly selected and tagged for recording the biometric observations at different growth stages. The observations on growth attributes were recorded at 20, 40 days after sowing and at harvest. Yield attributes and yield were recorded at harvest.

3.8.1 Growth attributes

Biometric observation on crop growth characters were recorded from the marked area of the net plot at 20, 40 and at harvest.

3.8.1.1 Initial plant population.

Initial plant population was recorded at 15 DAS from five randomly selected sites of one metre row length in net plot with the help of 1 m² quadrat as initial plant population m⁻² and the mean values were worked out and recorded for each plot.

3.8.1.2 Plant population at harvest

The plant population at harvest were recorded from five demarcated places with the help of 1 m² quadrat in each experimental plot average plant population was expressed as final plant population m⁻².

3.8.1.3 Plant height (cm)

Height of five randomly selected tagged plants from each plot was measured from base of the plants up to growing tip of main stem and average height was expressed in cm.

3.8.1.4 Number of leaves plant⁻¹

Number of leaves plant⁻¹ were recorded for each plot from the randomly selected five plants at 20, 40 days after sowing and at harvest, averaged and expressed as number of leaves per plant for each plot.

3.8.1.5 Shoot fresh weight (g)

Plant biomass of five tagged plants was taken at 20, 40 DAS and at harvest, averaged and expressed as shoot fresh weight.

3.8.1.6 Dry matter accumulation (g)

For recording dry matter accumulation, 5 plants from each plot were cut from the ground level of border rows at 20, 40 DAS and at harvest. Sampled plants were sun dried first then oven dried at 70°C for 48 hours to get constant weight. Thereafter, the average dry weight was recorded as g plant⁻¹.

3.8.1.7 Root fresh weight (g)

Roots of plants were extracted with the help of soil cores around the plant in row from five places. The roots are separated from the surrounding soil over a sieve by hand such that the total roots were kept intact (Prathapar *et al.*, 1989). The roots intact were washed in water to remove adhered soil and fresh weight was recorded and expressed in g plant⁻¹.

3.8.1.8 Root dry weight (g)

Roots were sundried for 2-3days then dried in hot air oven at 70⁰C temperature for 48 hours to get constant weight. Values were recorded, averaged and expressed as dry weight in g plant⁻¹.

3.8.1.9 Number of node plant⁻¹

The nodes from five randomly tagged plants were counted, averaged and expressed as numbers of internodes plant⁻¹.

3.8.1.10 Number of internodes plant⁻¹

The internodes from five randomly tagged plants were counted, averaged and expressed as numbers of internodes plant⁻¹.

3.8.1.11 Leaf area index (LIA)

Leaves of five plants tagged from each plot were used for leaf area estimation and was recorded with a leaf area matter. The LAI was worked out using the formula as suggested by Radford (1967).

$$\text{LAI} = \frac{\text{leaf area (cm}^2\text{)}}{\text{Land area (cm}^2\text{)}}$$

3.8.2 Yield

First the border rows were harvested, bundled and removed from the plot.

3.8.2.1 Green fodder yield (q ha⁻¹)

Then the crop from net plot area of (m²) each plot was harvested close to the ground, bundled and weighed as green fodder yield expressed in q ha⁻¹.

3.8.2.2 Dry fodder yield (q ha⁻¹)

The green fodder harvested was sundried for 4 days then weighed and expressed as dry fodder yield in q ha⁻¹.

3.9 Soil parameters

Soil samples from each plot were collected after harvest of the crop and analyzed for available N, P, and K using standard procedures (Subbiah and Asija, 1956), (Olsens method, 1954) and (Jackson, 1973).

3.10 Custard apple (Variety- Mammoth)

Custard apple (*Annona squamosa* L.) is one of the delicious and nutritious fruits can be grown in areas with rainfall as low as 400 mm. It is erect, with a rounded or spreading crown and trunk 25-35 cm thick. Height of the tree ranges from 3.5 to 5.0 m. The leaves are deciduous, alternate, oblong or narrow-lancelet, 10-20 cm long, 2.5 cm wide with conspicuous veins. The tree bears fruit at the age of 6-7 year, average fruit weigh nearly 122 g and on an average 27of number of fruits per tree found. Fruit usually contain 77.8% moisture and 1-4% protein per 100 gram of the edible protein. Annonas are mostly consumed as desert fruit and they are also used in making ice-cream, jam, jelly etc.

3.11 Observation on fruit tree species

The following parameters of fruit trees were taken from three sample plants situated at border of the plot. The observations on growth attributes of custard apple trees were recorded at the time of sowing, 40 DAS and at harvest of experimental crop.

3.11.1 Height (m)

The height of fruit trees were measured from base of the plants up to growing tip of main stem. The average plant height was calculated by taking the mean of three observations and expressed in meter.

3.11.2 Canopy (m)

The canopy diameter of each fruit tree was recorded with the help of meter tape. The diameter was calculated by taking the mean of three observations and expressed in meter.

3.11.3 Shading area (m)

The shading area of the fruit tree was recorded with the help of meter tape. The shading area was measured as width and length in meter at three places and values were averaged.

3.11.4 Stem girth (cm)

The stem girth of custard apple was recorded from base of tree plants and expressed in cm.

3.11.5 Fruit per tree (No.)

Number of fruits per tree from three places were recorded, averaged and expressed as number of fruits per tree.

3.11.6 Fruit weight (g) and fruit yield (kg ha⁻¹)

Representative fruit samples from three trees were taken and their weight was recorded in gram expressed as fruit weight. The yield from the sample tree was taken, averaged and expressed as fruit yield in kg ha⁻¹.

3.12 Economics

The economics of treatments was calculated separately by taking into account the existing price of inputs and produce. The investment on seed, fertilizers, labour, and power for performing different operations such as ploughing, weeding, harvesting included on per hectare basis as per rate prevalent at the Agricultural Research Farm Rajiv Gandhi South Campus (B.H.U), Mirzapur.

3.12.1 Cost of cultivation (Rs ha⁻¹)

Cost of cultivation was calculated by taking into consideration all the expenses incurred during experimentation.

3.12.2 Gross return (Rs ha⁻¹)

Gross return was calculated by multiplying the total green fodder yield per hectare with the prevailing market price of the green fodder.

3.12.3 Net return (Rs ha⁻¹)

Net return (Rs ha⁻¹) was calculated with the help of the following formula:

$$\text{Net return (Rs ha}^{-1}\text{)} = \text{Gross return (Rs. ha}^{-1}\text{)} - \text{Cost of cultivation (Rs. ha}^{-1}\text{)}$$

3.12.4 Benefit: Cost ratio (B:C ratio)

The benefit: cost ratio for each treatment was calculated from net return divided by cost of cultivation. Benefit: Cost ratio was calculated with the help of the following formula:

$$\text{Benefit :cost ratio} = \frac{\text{Net return (Rs. ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs. ha}^{-1}\text{)}}$$

3.13 Statistical Analysis

For determining the significance between the treatment means and to draw valid conclusion, statistical analysis was done. Data collected on growth and yield of the experimental crop were tabulated and statistically analyzed as per the standard analysis of variance (Gomez and Gomez, 1984). The treatment differences were tested by 'F' test and difference of treatment mean was tested using critical differences at 5% level of probability.

If the variance ratio (F test) was found significant at 5% level of significance, the standard error of mean (S.Em.±) and critical differences (CD) were calculated for further treatment comparisons.

ANOVA TABLE

Source of variation	Degree of Freedom	Sum of Squares	Mean Sum of square	Cal F Value	Tab F Value at 5%
Replication	2				3.44
Seed rate	2				3.44
N levels	3				3.04
S × N	6				2.54
Error	22				
Total	35				

EXPERIMENTAL FINDINGS

The present investigation entitled “**Effect of seed rate and nitrogen levels on fodder sorghum under custard apple (*Annona squamosa* L.) based horti-pastoral system**” was conducted during *kharif* season, 2016. An endeavor has been made in this chapter to assess the relative influence of various seed rate and nitrogen levels on crop growth at successive stages and on fodder yield. The data collected during the course of investigation has been statistically analyzed and presented in this chapter with the help of tables and depicted graphically. Studies on different growth parameters at different stages (20, 40 DAS and harvest), fresh and dry weight of fodder, and soil fertility status were recorded during experimentation.

4.1 Growth parameters

4.1.1 Plant population

Initial and final plant population of fodder sorghum as influenced by seed rate and nitrogen levels is presented in Table 4.1.

From the data it is evident that plant population (initial and final) significantly varied among themselves due to seed rate. As the seed rate increased, the plant population also increased and maximum initial population (37.43) and final population (34.41) was observed at highest seed rate *i.e.* 50 kg ha⁻¹ followed by 40 kg ha⁻¹. Significantly lowest plant population was recorded with lower seed rate (30 kg ha⁻¹).

The data revealed that initial and final plant population of fodder sorghum was significantly influenced by different nitrogen levels. With increasing levels of nitrogen, plant population increased and maximum population (initial and final) was registered with highest level of nitrogen (120 kg ha⁻¹) and minimum with control. The order of plant population with respect to nitrogen level was $N_4 > N_3 > N_2 > N_1$.

The interaction effect of seed rate and nitrogen levels was non-significant.

Table 4.1: Initial and final plant population m⁻² of fodder sorghum as influenced by seed rates and nitrogen levels under custard apple based horti-pastoral system.

Treatment	Initial Plant population (m⁻²)	Final plant population (m⁻²)
Seed rate (kg ha⁻¹)		
S ₁ : 30	26.77	23.83
S ₂ : 40	30.32	27.33
S ₃ : 50	37.43	34.41
SEm±	0.64	0.63
LSD (P=0.05)	1.89	1.87
Nitrogen Levels (kg ha⁻¹)		
N ₁ : control	24.25	21.33
N ₂ : 40	30.44	27.22
N ₃ : 80	33.84	30.88
N ₄ : 120	37.51	34.66
SEm±	0.74	0.73
LSD (P=0.05)	2.18	2.16
Interaction	NS	NS

4.1.2 Plant height (cm)

Data pertaining to the plant height recorded at successive growth stages (20, 40 DAS and harvest) are presented in Table 4.2. From the data it was obvious that plant height continuously increased with the age of plant up to harvest and a maximum increase in plant height was found between 20 and 40 DAS.

Significant differences in the plant height by seed rates were observed during all the stages of growth. Taller plants were produced by 50 kg ha⁻¹ followed by 40 kg ha⁻¹ and 30 kg ha⁻¹ at 20 DAS. Similar trend was observed at 40 DAS and harvest.

Nitrogen application @ 120 kg ha⁻¹ recorded maximum plant height which was significantly superior to all other nitrogen levels at all the growth stages. Shortest plants were obtained with control treatment at all growth stages. The trend for plant height at all growth stages was N₄ > N₃ > N₂ > N₁.

Interaction of seed rate and nitrogen levels did not turn up significant.

4.1.3 Number of leaves plant⁻¹

Data pertaining to the number of leaves plant⁻¹ recorded at respective growth stages are presented in Table 4.3. Number of leaves continuously increased with the age of plant and maximum values registered at harvest.

Significant differences in the number of leaves by seed rate were observed during all the stages of growth. Maximum numbers of leaves were produced by seed rate of 30 kg ha⁻¹, second best treatment was recorded with 40 kg ha⁻¹ and 50 kg ha⁻¹ was least effective at 20 DAS. The trend was similar at remaining stages of growth *i.e.* 40 DAS and harvest.

It is clear that number of leaves plant⁻¹ of fodder sorghum significantly varied by different nitrogen levels. Highest dose of nitrogen (120 kg ha⁻¹) recorded maximum number of leaves significantly superior to N₂ and N₁, respectively (20, 40 DAS and harvest) at all growth stages.

The interaction of seed rate and nitrogen levels could not turn up significant

Table 4.2: Plant height (cm) of fodder sorghum at different growth stages as influenced by seed rates and nitrogen levels under custard apple based horti-pastoral system.

Treatments	Plant height (cm)		
	20 DAS	40 DAS	Harvest
Seed rate (kg ha⁻¹)			
S ₁ : 30	59.85	140.68	172.67
S ₂ : 40	67.78	159.31	195.53
S ₃ : 50	83.67	196.67	241.39
SEm±	1.44	3.39	4.16
LSD (<i>P</i> =0.05)	4.23	9.96	12.22
Nitrogen Levels (kg ha⁻¹)			
N ₁ : control	54.21	127.42	156.39
N ₂ : 40	68.03	159.91	196.27
N ₃ : 80	75.64	177.80	218.22
N ₄ : 120	83.85	197.09	241.91
SEm±	1.66	3.92	4.81
LSD (<i>P</i> =0.05)	4.89	11.50	14.11
Interaction	NS	NS	NS

Table 4.3: Number of leaves plant⁻¹ of fodder sorghum at different growth stages as influenced by seed rates and nitrogen levels under custard apple based horti-pastoral system.

Treatments	Number of leaves		
	20 DAS	40 DAS	At harvest
Seed rate (kg ha⁻¹)			
S ₁ : 30	6.15	8.16	10.62
S ₂ : 40	4.98	6.61	8.60
S ₃ : 50	4.40	5.83	7.59
SEm±	0.10	0.14	0.18
LSD (<i>P</i> =0.05)	0.31	0.41	0.53
Nitrogen Levels (kg ha⁻¹)			
N ₁ : control	3.98	5.28	6.88
N ₂ : 40	5.00	6.63	8.63
N ₃ : 80	5.56	7.37	9.60
N ₄ : 120	6.16	8.18	10.64
SEm±	0.12	0.16	0.21
LSD (<i>P</i> =0.05)	0.36	0.47	0.62
Interaction	NS	NS	NS

4.1.4 Number of nodes plant⁻¹

Data pertaining to the number of nodes plant⁻¹ recorded at successive growth stages are presented in Table 4.4. Number of nodes increased till harvest and maximum increase in number of nodes was found between 40 DAS and harvest.

Number of nodes differed significantly by seed rate at all the growth stages. Higher number of nodes was obtained with 50 kg ha⁻¹ followed by 40 kg ha⁻¹ and 30 kg ha⁻¹ at all growth stages *i.e.* at 20, 40 DAS and harvest. The trend of seed rate was $S_3 > S_2 > S_1$.

Highest number of nodes was noted by nitrogen level of 120 kg ha⁻¹ at all the growth stages. Number of nodes significantly differed among the nitrogen levels at all growth stages (20, 40 DAS and harvest). The number of nodes produced by 80 kg ha⁻¹ and 40 kg ha⁻¹ were second and third best treatments. Significantly lowest numbers of nodes were obtained with control treatment at all growth stages.

Interaction of seed rate and nitrogen levels did not turn up significant.

4.1.5 Number of internodes plant⁻¹

Data pertaining to the number of internodes plant⁻¹ at different growth stages revealed that internodes continuously increased with the development in age of plant up to harvest and are presented in Table 4.5.

Significant differences in the number of internodes by seed rate were observed during all the growth stages. Number of internodes increased with the seed rate and more internodes were obtained by 50 kg ha⁻¹ followed by 40 kg and 30 kg ha⁻¹ seed rate at 20 DAS. Similar trend observed at 40 DAS and at harvest.

Nitrogen application (120 kg ha⁻¹) recorded significantly higher number of internodes than other levels at all the growth stages. Significantly lowest number of internodes was obtained with control treatment at all growth stages. Number of internodes were in order of $N_4 > N_3 > N_2 > N_1$ at all growth stages.

Interaction between seed rate and nitrogen levels could not turn up significant.

Table 4.4: Number of nodes plant⁻¹ of fodder sorghum at different growth stages as influenced by various seed rate and nitrogen levels under custard apple based horti-pastoral system.

Treatments	Number of nodes		
	20 DAS	40 DAS	At harvest
Seed rate (kg ha⁻¹)			
S ₁ : 30	1.96	3.76	5.95
S ₂ : 40	2.22	4.26	6.74
S ₃ : 50	2.74	5.26	8.33
SEm±	0.04	0.09	0.14
LSD (<i>P</i> =0.05)	0.13	0.26	0.42
Nitrogen Levels (kg ha⁻¹)			
N ₁ : control	1.78	3.40	5.39
N ₂ : 40	2.23	4.27	6.77
N ₃ : 80	2.48	4.75	7.53
N ₄ : 120	2.75	5.27	8.34
SEm±	0.05	0.10	0.16
LSD (<i>P</i> =0.05)	0.16	0.30	0.48
Interaction	NS	NS	NS

Table 4.5: Number of internodes plant⁻¹ of fodder sorghum at different growth stages as influenced by various seed rate and nitrogen levels under custard apple based horti-pastoral system.

Treatments	Number of internodes		
	20 DAS	40 DAS	At harvest
Seed rate (kg ha⁻¹)			
S ₁ : 30	1.05	2.87	4.71
S ₂ : 40	1.19	3.25	5.65
S ₃ : 50	1.47	4.01	7.53
SEm±	0.02	0.06	0.17
LSD (<i>P</i> =0.05)	0.07	0.20	0.50
Nitrogen Levels (kg ha⁻¹)			
N ₁ : control	0.95	2.60	4.03
N ₂ : 40	1.19	3.26	5.68
N ₃ : 80	1.32	3.62	6.58
N ₄ : 120	1.47	4.02	7.56
SEm±	0.02	0.08	0.19
LSD (<i>P</i> =0.05)	0.08	0.23	0.58
Interaction	NS	NS	NS

4.1.6 Leaf area index

Leaf area index recorded at successive growth stages are presented in Table 4.6. Data revealed that leaf area index continuously increased with the age of plant up to harvest and greatest increase in leaf area index was found between 20 DAS and 40 DAS.

Leaf area index significantly altered at all growth stages due to seed rate. Significantly maximum leaf area index was produced by using lowest seed rate of 30 kg ha⁻¹. With increasing seed rate from 30 to 50 kg ha⁻¹ leaf area index decreased significantly at 20 DAS. The trend was similar at 40 DAS and harvest.

Nitrogen levels have significant influence on leaf area index at all stages and differed significantly among themselves. Application of 120 kg N ha⁻¹ recorded significantly higher leaf area index than other nitrogen levels at all the growth stages. Lowest leaf area index was registered with control treatment at all growth stages.

Interaction of seed rate and nitrogen levels was non-significant.

Table 4.6: Leaf area index plant⁻¹ of fodder sorghum at different growth stage as influenced by various seed rate and nitrogen levels under custard apple based horti pastoral system.

Treatments	Leaf area Index		
	20 DAS	40 DAS	At harvest
Seed rate (kg ha⁻¹)			
S ₁ : 30	1.48	7.93	11.71
S ₂ : 40	1.20	6.42	9.48
S ₃ : 50	1.06	5.67	8.37
SEm±	0.02	0.13	0.20
LSD (<i>P</i> =0.05)	0.07	0.40	0.59
Nitrogen Levels (kg ha⁻¹)			
N ₁ : control	0.96	5.13	7.58
N ₂ : 40	1.20	6.45	9.52
N ₃ : 80	1.33	7.17	10.58
N ₄ : 120	1.48	7.95	11.73
SEm±	0.02	0.15	0.23
LSD (<i>P</i> =0.05)	0.08	0.46	0.68
Interaction	NS	NS	NS

4.1.7 Shoot fresh weight plant⁻¹(g)

Data pertaining to the shoot fresh weight plant⁻¹ recorded at successive growth stages are presented in Table 4.7.

At all growth stages significant differences in the shoot fresh weight were noted by seed rates used. Maximum biomass was produced by 30 kg ha⁻¹ followed by 40 kg ha⁻¹ and 50 kg ha⁻¹ at 20, 40 DAS and harvest.

Nitrogen application @ 120 kg ha⁻¹ recorded greater fresh weight significantly superior followed by 80, 40 kg N ha⁻¹ and control at all growth stages.

Interaction could not differ significantly.

4.1.8 Shoot dry weight plant⁻¹ (g)

Shoot dry weight plant⁻¹ varied due to seed rate and nitrogen levels at successive growth stages presented in Table 4.8. Dry weight increased from 20 DAS to harvest during course of investigation.

Shoot dry weight showed significant differences due to seed rate at all the growth stages. Significantly superior dry weight was produced by 30 kg ha⁻¹ seed rate followed by 40 kg ha⁻¹ and 50 kg ha⁻¹ at 20, 40 DAS and harvest.

Nitrogen levels significantly differed among themselves with respect to shoot dry weight. With increasing level of nitrogen biomass increased and maximum dry weight was registered with highest level of nitrogen (120 kg ha⁻¹) and minimum dry weight was noted by no nitrogen application. The order with respect to nitrogen level was N₄ > N₃ > N₂ > N₁.

Interaction of seed rate and nitrogen levels did not turn up significant.

Table 4.7: Shoot fresh weight plant⁻¹ (g) of fodder sorghum at different growth stages as influenced by various seed rate and nitrogen levels under custard apple based horti-pastoral system.

Treatments	Shoot fresh weight (g)		
	20 DAS	40 DAS	At harvest
Seed rate (kg ha⁻¹)			
S ₁ : 30	12.78	48.90	80.88
S ₂ : 40	10.35	39.61	65.51
S ₃ : 50	9.14	34.98	57.85
SEm±	0.22	0.84	1.39
LSD (P=0.05)	0.64	2.47	4.09
Nitrogen Levels (kg ha⁻¹)			
N ₁ : control	8.28	31.68	52.40
N ₂ : 40	10.39	39.76	65.76
N ₃ : 80	11.55	44.21	73.11
N ₄ : 120	12.81	49.01	81.05
SEm±	0.25	0.97	1.61
LSD (P=0.05)	0.74	2.86	4.73
Interaction	NS	NS	NS

Table 4.8: Shoot dry weight plant⁻¹ (g) of fodder sorghum at different growth stages as influenced by various seed rate and nitrogen levels under custard apple based horti-pastoral system.

Treatments	Shoot dry weight (g)		
	20 DAS	40 DAS	At harvest
Seed rate (kg ha⁻¹)			
S ₁ : 30	1.43	6.54	19.91
S ₂ : 40	1.16	5.30	16.12
S ₃ : 50	1.02	4.68	14.24
SEm±	0.02	0.11	0.34
LSD (<i>P</i> =0.05)	0.07	0.33	1.00
Nitrogen Levels (kg ha⁻¹)			
N ₁ : control	0.92	4.22	12.90
N ₂ : 40	1.16	5.32	16.19
N ₃ : 80	1.29	5.91	18.00
N ₄ : 120	1.43	6.55	19.95
SEm±	0.02	0.13	0.39
LSD (<i>P</i> =0.05)	0.08	0.38	1.16
Interaction	NS	NS	NS

4.1.9 Root fresh weight plant⁻¹ (g)

Data related to the root fresh weight plant⁻¹ recorded at consecutive growth stages are presented in Table 4.9. Fresh weight continuously increased with the age of plant up to harvest.

Significant differences in the root fresh weight by seed rate were observed during 20, 40 DAS and harvest. Lower seed rate (30 kg ha⁻¹) resulted in greater fresh weight followed by 40 kg ha⁻¹ and 50 kg ha⁻¹ at 20 DAS. Similar trend was observed at rest of the growth stages *i.e.* 40 DAS and harvest.

Significantly superior root fresh weight was noted by highest level of nitrogen (120 kg ha⁻¹) and was significantly superior to all other nitrogen levels at all the growth stages. Applying 80 kg N ha⁻¹ has registered the next best fresh weight. 40 kg N ha⁻¹ proved best only to control treatment at all growth stages.

Interaction of seed rate and nitrogen levels could not differ significantly.

4.1.10 Root dry weight plant⁻¹ (g)

Dry weight plant⁻¹ recorded at successive growth stages are presented in Table 4.10. From the data it was evident that dry weight continued to increase with the age of plants up to harvest, a rapid increase was noticed between 40 DAS and harvest.

Dry weight varied significantly due to seed rate at all the stages of growth. Maximum dry weights were produced by lowest seed rate of 30 kg ha⁻¹ followed by higher seed rates 40 kg ha⁻¹ and 50 kg ha⁻¹, respectively at 20 DAS. Similar trend was observed at both 40 DAS and harvest.

Nitrogen levels have significant influence on dry weight at all stages and differed significantly among themselves. Application of 120 kg N ha⁻¹ recorded higher dry weight which was significantly superior to all other nitrogen levels at all the growth stages. Lower dry weight was registered with control treatment at all growth stages. The trend was N₄ > N₃ > N₂ > N₁ at all growth stages.

Interaction of seed rate and nitrogen levels did not turn up significant.

Table 4.9: Root fresh weight plant⁻¹ (g) of fodder sorghum at different growth stage as influenced by various seed rate and nitrogen levels under custard apple based horti-pastoral system.

Treatments	Root fresh weight (g)		
	20 DAS	40 DAS	At harvest
Seed rate (kg ha⁻¹)			
S ₁ : 30	0.97	2.18	6.56
S ₂ : 40	0.79	1.76	5.31
S ₃ : 50	0.69	1.56	4.69
SEm±	0.01	0.03	0.11
LSD (<i>P</i> =0.05)	0.04	0.11	0.33
Nitrogen Levels (kg ha⁻¹)			
N ₁ : control	0.63	1.41	4.25
N ₂ : 40	0.79	1.77	5.33
N ₃ : 80	0.88	1.97	5.93
N ₄ : 120	0.97	2.18	6.58
SEm±	0.01	0.04	0.13
LSD (<i>P</i> =0.05)	0.05	0.12	0.38
Interaction	NS	NS	NS

Table 4.10: Root dry weight plant⁻¹ (g) as influenced by various seed rate and nitrogen levels on fodder sorghum under custard apple based hortipastoral system at various growth stages.

Treatments	Root dry weight (g)		
	20 DAS	40 DAS	At harvest
Seed rate (kg ha⁻¹)			
S ₁ : 30	0.26	0.96	3.06
S ₂ : 40	0.21	0.78	2.48
S ₃ : 50	0.19	0.69	2.19
SEm±	0.004	0.01	0.05
LSD (<i>P</i> =0.05)	0.01	0.04	0.15
Nitrogen Levels (kg ha⁻¹)			
N ₁ : control	0.17	0.62	1.98
N ₂ : 40	0.21	0.78	2.49
N ₃ : 80	0.24	0.87	2.77
N ₄ : 120	0.27	0.97	3.07
SEm±	0.005	0.01	0.06
LSD (<i>P</i> =0.05)	0.01	0.05	0.17
Interaction	NS	NS	NS

4.1.11 Green fodder yield

Green fodder yield was recorded at harvest and is presented in Table 4.11.

A significant difference in the green fodder yield by seed rate was observed and differed significantly at harvest. Maximum green fodder yield were produced by highest seed rate (50 kg ha⁻¹) followed by 40 kg ha⁻¹ and 30 kg ha⁻¹ at harvest.

Nitrogen application @ 120 kg ha⁻¹ recorded maximum green forage yield which was significantly superior to all other nitrogen levels at harvest. Minimum green forage yield were obtained with control treatment at harvest. The trend for green forage yield at harvest was N₄ > N₃ > N₂ > N₁.

Interaction of seed rate and nitrogen levels could not differ significantly.

4.1.12 Dry fodder yield

Data related to dry fodder yield recorded at harvest is presented in Table 4.11.

Dry fodder yield increased significantly due to seed rate at harvest. Dry fodder yield differed significantly among themselves with the highest values being noted by greater seed rate (50 kg ha⁻¹). Second best treatment regarding dry fodder yield was obtained with 40 kg ha⁻¹ and least yield was noted by 30 kg ha⁻¹ at harvest.

Nitrogen levels varied significantly among themselves for dry fodder yield. Nitrogen application of 120 kg ha⁻¹ recorded maximum dry fodder yield at harvest. As the nitrogen application reduced from 120 kg ha⁻¹ to 0 kg ha⁻¹ dry fodder yield reduced significantly. The trend for yield was N₄ > N₃ > N₂ > N₁.

Interaction of seed rate and nitrogen levels did not turn up significant.

Table 4.11: Green and dry fodder yield (q ha^{-1}) of fodder sorghum at harvest as influenced by various seed rate and nitrogen levels under custard apple based horti-pastoral system.

Treatment	Green fodder yield (q ha^{-1})	Dry fodder yield (q ha^{-1})
Seed rate (kg ha^{-1})		
S ₁ : 30	84.07	28.02
S ₂ : 40	109.45	35.06
S ₃ : 50	117.11	39.34
SEm±	2.46	0.70
LSD ($P=0.05$)	7.21	2.06
Nitrogen Levels (kg ha^{-1})		
N ₁ : control	83.37	26.49
N ₂ : 40	99.12	32.96
N ₃ : 80	109.92	36.75
N ₄ : 120	121.78	40.37
SEm±	2.84	0.81
LSD ($P=0.05$)	8.33	2.38
Interaction	NS	NS

4.2. Available nitrogen, phosphorus and potassium (kg ha⁻¹) in soil

Data regarding residual soil fertility status after harvest as influenced by different treatments are presented in table 4.12. Available nitrogen did not vary significantly due to seed rate only. N levels caused variation in available nitrogen with highest values recorded by 120 kg N ha⁻¹ and it could not differ with that of 80 kg N ha⁻¹ only. N₂ and N₁ differed significantly with each other, lowest values obtained with N₁. Available phosphorus and potassium found non- significant with the seed rate and nitrogen levels.

Interaction of seed rate and nitrogen levels did not turn up significant.

4.3 Relative economics

Research finding may be useful from academic point of view but would not be useful to the farmers unless these findings are economically feasible from the point of its adoption by beneficiaries. The economic analysis includes the cost of cultivation, gross return, net return and benefit: cost ratio for different treatment combination, and the data in respect of economics have been summarized in Table 4.13.

Table 4.12 Available N, P and K after harvest of fodder sorghum as influenced by various seed rate and nitrogen levels under custard apple based hortipastoral system.

Treatments	Available N (kg ha⁻¹)	Available P (kg ha⁻¹)	Available K (kg ha⁻¹)
Seed rate (kg ha⁻¹)			
S ₁ : 30	215.36	17.03	185.80
S ₂ : 40	214.22	16.73	180.23
S ₃ : 50	207.66	16.33	179.65
SEm±	2.56	0.40	3.23
LSD (<i>P</i> =0.05)	NS	NS	NS
Nitrogen Levels (kg ha⁻¹)			
N ₁ : control	197.55	16.32	173.42
N ₂ : 40	212.50	16.52	181.6
N ₃ : 80	218.00	16.85	184.22
N ₄ : 120	221.62	17.09	188.35
SEm±	2.96	0.46	3.73
LSD (<i>P</i> =0.05)	8.69	NS	NS
Interaction	NS	NS	NS

Table 4.13 Effect of seed rate and nitrogen levels on relative economics of fodder sorghum under custard apple based horti-pastoral system.

Treatment	Cost of cultivation	Green fodder (Rs ha⁻¹)	Custard apple (fruit) (Rs ha⁻¹)	Total gross return (Rs ha⁻¹)	Net return (Rs ha⁻¹)	Benefit: cost Ratio
S ₁ N ₁	15929.80	16760.00	33468.00	50228.00	34298.20	2.15
S ₁ N ₂	16145.92	20277.50	33468.00	53745.50	37599.58	2.32
S ₁ N ₃	16666.72	22422.50	33468.00	55890.50	39223.78	2.35
S ₁ N ₄	17187.52	24615.00	33468.00	58083.00	40895.48	2.37
S ₂ N ₁	16879.80	22282.50	33468.00	55750.50	38870.70	2.30
S ₂ N ₂	17095.92	24920.00	33468.00	58388.00	41292.08	2.41
S ₂ N ₃	17616.72	28775.00	33468.00	62243.00	44626.28	2.53
S ₂ N ₄	18137.52	33477.50	33468.00	66945.50	48807.98	2.69
S ₃ N ₁	17829.80	23485.00	33468.00	56953.00	39123.20	2.19
S ₃ N ₂	18045.92	29142.50	33468.00	62610.50	44564.58	2.46
S ₃ N ₃	18566.72	31240.00	33468.00	64708.00	46141.28	2.48
S ₃ N ₄	19087.52	33240.00	33468.00	66715.50	47627.98	2.49

Green forage price- Rs 2.50/ kg

4.3.1 Cost of cultivation (Rs ha⁻¹)

The common cost of cultivation of different treatment combinations were worked out, considering all the operations from land preparation to harvesting and input used. The treatment cost was calculated separately and it was combined with common cost of cultivation to find out the total cost of cultivation. Data revealed that the cost of cultivation was maximum (Rs. 19087.52 ha⁻¹) for 50 kg ha⁻¹ + 120 kg ha⁻¹ (S₃N₄), over rest of the treatments. The total cost of cultivation was minimum (Rs. 15929.8 ha⁻¹) under the control treatment (S₁ N₁).

4.3.2 Gross return (Rs ha⁻¹)

It is evident from the data that among different treatment combinations maximum gross return of Rs. 66945.5 ha⁻¹ was obtained with 40 kg ha⁻¹ + 120 kg ha⁻¹ in custard apple based horti-pastoral system. The minimum gross return of Rs.50228 per hectare was recorded with control treatment.

4.3.3 Net return (Rs ha⁻¹)

The net return was markedly influenced due to different costs incurred and yield (green fodder yield) obtained under various treatments. The maximum and minimum net return was recorded under application of 40 kg ha⁻¹ + 120 kg ha⁻¹ (S₂N₄) and minimum under control treatment (S₁N₁) treatment, respectively.

4.3.4 Benefit: cost ratio

The data on benefit: cost ratio indicated that the maximum benefit: cost ratio (2.69) was recorded in combined application of 40 kg ha⁻¹ seed with 120 kg ha⁻¹ nitrogen under custard apple based horti-pastoral system. However, the treatment S₁N₁ incurred the minimum benefit: cost ratio (2.15).

4.4 Growth parameters of fruit tree species

4.4.1 Plant height (m)

The data pertaining to growth parameters of custard apple at different crop growth stages are presented in table 4.14. It is evident from the data that the average tree height marginally increased during the experimental crop period which was 4.73 m at the time of sowing and reached to 4.92 m at harvest.

4.4.2 Canopy diameter (m)

Maximum canopy of fruit tree species (4.49 m) was recorded at the time of harvesting of the field crop (fodder sorghum) and minimum (3.84 m) was found at the time of sowing of crop.

4.4.3 Stem girth (cm)

Maximum stem girth of fruit tree species (42.95 cm) was recorded at the time of harvesting of the field crop (fodder sorghum) and minimum (42.12 cm) was found at the time of sowing of crop.

4.4.4 Shading area

At the time of sowing length of shading area was recorded (4.10 m) which reached to maximum (4.41 m) at the time of harvesting of fodder sorghum. In case of width of shading area minimum was recorded at the time of sowing (3.89 m) and maximum area (4.12 m) obtained at the time of harvesting of fodder sorghum.

4.4.5 Yield attributes, yield, and economic return from (custard apple)

4.4.5.1 Yield attributes

The yield contributing characters of fruit tree viz. average number of fruit, average fruit weight and number of fruit trees ha⁻¹ were measured at harvest and presented in table 4.15. Data shows that the numbers of average fruits tree⁻¹ were 38.62 and average weight of fruit (g) was found to be 79.93 g and number of fruit trees ha⁻¹ noted was 380 ha⁻¹.

4.4.5.2 Fruit yield

The yield of custard apple (836.7 kg ha⁻¹) was estimated by multiplying the yield contributing characters of fruit tree viz. average number of fruit, average fruit weight and number of fruit trees ha⁻¹ were measured at harvest.

4.4.5.3 Gross income

The gross income obtained from fruit component was Rs. 33468 ha⁻¹ which was taken as a common gross return ha⁻¹ and added to the gross return of each treatment.

Table 4.14 Growth parameters of custard apple at sowing

Particulars		At sowing	At harvest
1.Height (m)		4.73	4.92
2.Canopy diameter (m)		3.84	4.49
3.Stem girth (cm)		42.12	42.95
4.Shading area	Length (m)	4.10	4.41
	Width (m)	3.89	4.12

**Table 4.15 Yield attributes, yield and economic return from fruit component
(custard apple)**

Fruit tree	Average fruit tree⁻¹	Average weight of fruit (g)	No. of fruit trees ha⁻¹	Average fruit yield (kg ha⁻¹)	Rate of fruit (Rs.kg⁻¹)	Grass income (Rs. ha⁻¹)
Custard apple	38.62	79.93	380	836.7	40.00	33468

DISCUSSION

The present investigation entitled “**Effect of seed rate and nitrogen levels on fodder sorghum under custard apple (*Annona squamosa* L.) based horti-pastoral system**” was conducted during rainy (*khariif*) season of 2016 at Agricultural Research Farm of Rajiv Gandhi South Campus, Barkaccha (BHU), Mirzapur, Uttar Pradesh. In this chapter an attempt has been made to analyze the important observations recorded during course of experimentation in the light of cause, effect and relationship (Various influences due to the variation in treatment combinations and their influence on soil as well as crops have been described in this chapter).

The growth and yield potentiality of crop mainly depends upon its genetic characters as well as the environmental factors to some extent. Yield is the cumulative effect of growth and developmental parameters, size of the photosynthetic system and its efficiency translocation of photosynthate to sink. The growth and development of crops is greatly influenced by the alley cropping system and have shown fluctuation of indirect or direct effect on growth and development.

The finding of experiment presented in preceding chapter has been discussed with possible reasons of variation by experimental variables on different parameter duly supported by available literature.

5.1 Effect of weather on crop

Crop growth is prominently governed by weather. Any discussion of the results would, therefore, be not appropriate without taking into consideration the weather relationship with crop to arrive at correct interpretation and conclusion.

The weather factors *viz.*, rainfall, temperature (minimum and maximum) and relative humidity recorded during crop duration of the present experimentation are given in Table 3.1 and depicted in Fig. 3.1. The variation in weather parameters has pronounced effect on growth and development of the crop. For achieving the yield potential every crop has its own cardinal point of air temperature, relative humidity,

vapor pressure, and sunshine duration. If the fluctuation becomes too wide from optimum, the plants suffer leading to poor growth, development and yield. This effect is more pronounced in crops which are grown in diverse climatic and edaphic conditions.

Every crop requires a set of definite environmental condition for its proper growth and development. Sorghum tolerates drought particular growing does not require condition but grows in warmer region. It is a generally grown as *kharif* season crop in northern India. Heavy rainfall particularly during the flowering stage is harmful and adversely affects the production.

Temperature is known to have strong effect on vegetative and reproductive phases. The unusual temperature severely affects germination and plant stand. The meteorological data (Table 3.2) recorded during the crop season showed that the average temperature was within the optimum range (20.3-35.1°C) for growth of sorghum. The rainfall received (179.9 mm) during the study was low but well distributed and during the harvest stage occurrence of dry weather supported the growth and yield of crop.

5.2 Effect on crop

5.2.1 Effect of seed rate

5.2.1.1 Effect on growth parameters

Growth characters (initial plant population, final plant population, plant height, number of leaves, number of nodes, number of internodes, leaf area index, fresh weight and dry weight in plant and root) were significantly influenced by seed rate at 20, 40 DAS and at harvest. Maximum plant population (initial and final) was obtained by 50 kg ha⁻¹ seed rate. The population increased as seed rate increased and density of plants is mainly governed by the seed rate. The similar findings of seed rate on initial and final population were reported by Gasim *et al.* (2001), Ayub *et al.* (2002) and Ayub *et al.* (2007).

Plant height of fodder sorghum increased with increase in seed rate from 30 to 50 kg ha⁻¹ at different crop growth periods. The plant height showed increasing trend

up to harvest irrespective of seed rates and magnitude of increase was highly pronounced from 20 to 40 DAS. Amongst other factors, the plant height is controlled by genetic makeup of the species and the environment to which plants are subjected during the growth and development. Further, shading effect causes the auxins to move from illuminated side to shade side and thus the imbalance of auxin causes more elongation of plants in shade with curvature compared to being in light. Since auxin is sensitive to light, shading prevents its destruction and thus higher accumulation of auxin in shady plants triggers its growth to height. Joshi and Kumar (2007) found that seed rate of 60 kg ha⁻¹ significantly increased the plant height over 50 kg ha⁻¹. Similar result was found by Mahdi *et al.* (2011).

The present study revealed a gradual increase in the leaf area index of fodder sorghum up to harvest irrespective of treatments and the increase were more pronounced from 20 to 40 DAS. Further, leaf area index decreased with increase in seed rate of from 30 to 50 kg ha⁻¹. The higher leaf area index with lower seed rate was due to better nutrient, sunlight and moisture. At higher seed rate, the low leaf area index was mainly due to competition for light. These results could be attributed to the effect of low plant population on vegetative and reproductive development. Intact physiological growth indices in sorghum are low with low plant density because of little plasticity in leaf area per plant. Similar findings have also been made by Valadabadi and Farahani (2010).

Maximum number of leaves plant⁻¹ was obtained by seed rate 30 kg ha⁻¹. Increase in seed rate significantly decreased number of leaves plant⁻¹. The decrease in number of leaves with increased plant density might have been due to more competition for space, water and nutrients. These results are in conformity with those of Shabbir (1997) and Ayub *et al.* (2003).

Dry matter production, nodes and internodes plant⁻¹, fresh and dry weight of root and shoot recorded with 30 kg seed rate ha⁻¹ at different crop growth periods was significantly higher than 40 and 50 kg ha⁻¹. Increase in dry matter production, internodes plant⁻¹, fresh and dry weight of root with increased seed rate was mainly due to more plant density, plant height, leaf area and functional leaves per unit area. Dry matter production, internodes plant⁻¹, fresh and dry weight of root is related to the

amount of solar radiation intercepted by the canopy. At lower plant density, the canopy expands more rapidly, more radiation is intercepted that results in greater growth parameter. The similar findings of seed rate on dry matter production, internodes plant⁻¹, fresh and dry weight of root were reported by Ayub *et al.* (2007) and Valadabadi and Farhani (2010).

5.2.1.2 Effect on yield

Significantly higher dry fodder yield recorded with highest seed rate (50 kg ha⁻¹) could be attributed to increased plant height, more number of leaves per unit area and leaf area. Earlier Ayub *et al.* (1999), Malik *et al.* (2007) and Osman *et al.* (2010) also reported significant improvement in the dry fodder yield at higher seed rates.

Green fodder yield also enhanced with increase in seed rate from 30 to 50 kg ha⁻¹. Increase in green fodder yield at higher seed rate may be due to more number of plants per unit area, higher plant height and leaf area index. Similar results have also been reported earlier by Amanullah *et al.* (2009). The superior yield with higher seed rate was higher dry matter with is related to amount of solar radiation intercepted by the canopy.

5.2.2 Effect of nitrogen

5.2.2.1 Effect on growth parameters

In the present study growth characters (Initial plant population, final plant population, plant height, number of leaves, number of nodes, number of internodes, leaf area index, fresh weight and dry weight in plant and root) were significantly influenced by nitrogen levels at 20, 40 DAS and at harvest. Maximum plant population (initial and final) was obtained by 120 kg N ha⁻¹. Abusuwar and Mohammed (1997) reported that nitrogen fertilization had a significant effect on plant density of fodder sorghum.

Increase in plant height with higher dose of N may be due to increased number of node and/or internodes elongation. These findings are in accordance with Abusuwar and Mohammed (1997) and Elbetib (2004).

Plant height is the index of plant growth and significant improvement was visible at different crop growth stages due to increase in the nitrogen rates from 0 to 120 kg ha⁻¹. Maximum plant height number of leaves, nodes and internodes was obtained by 120 kg ha⁻¹ N. Higher plant height with increase in nitrogen levels was mainly attributed to sufficient availability and more uptake of nitrogen by crop which resulted in more vegetative growth, increase in protoplasmic constituent and acceleration in the process of cell division, expansion and differentiation and there by resulting in luxuriant growth. The findings of Agarwal *et al.* (2005) and Tiwana and Puri (2005) confirmed these results. Increased number of forage sorghum leaves plant⁻¹ with application of nitrogen has also been reported by Backiyavathy *et al.* (2007), Ahmad *et al.* (2011) and Patil *et al.* (2014). Mustafa and Abdemased (1982) found little influence of nitrogen application on number of leaves. Enhancement in nitrogen levels significantly increases number and length of internodes plant⁻¹ (Patil *et al.*, 2014).

Leaf area index recorded discernible increase with increase in nitrogen level from 0 to 120 kg ha⁻¹. Moreover, leaf area index increased up to harvest, however; the magnitude of increase was more pronounced from 20 to 40 DAS. Nitrogen enhanced protein synthesis and consequently vegetative growth and increased LAI resulted increase in photosynthetic surface and stimulated the growth further. The above results are in confirmation with Eltelib (2004) and Osman *et al.* (2010).

Significantly higher dry matter production, fresh and dry weight of root plant⁻¹ was obtained by 120 kg N ha⁻¹. Increased quantity of nitrogen provided larger photosynthetic surface area to intercept more radiant energy and ultimately more active plant growth and consecutively resulted in more dry matter production, fresh and dry weight of root plant⁻¹. Similar results were reported by Mahmud *et al.* (2003), Singh *et al.* (2005) and Yadav *et al.* (2007).

5.2.2.2 Effect on yield

Highest fodder yield obtained with 120 kg N ha⁻¹. Higher nitrogen improved the growth viz. plant height, number of leaves, dry matter and also exerted beneficial effects on cell division and elongation, formation of nucleotides and co-enzymes and their by increased meristematic activity and photosynthetic area. Hence, more production and accumulation of photosynthates, yielded higher green fodder and dry

matter. These results are in conformity with the findings of Dudhat *et al.* (2004), Sharma and Verma (2005), Sheoran and Rana (2006), Trivedi (2011) and Somashekar *et al.* (2015).

5.3 Available NPK in the soil

Seed rate does not have significant influence on the available nutrient (NPK) status after harvest of fodder sorghum. However, increased application of nitrogen significantly increased the residual nitrogen, while phosphorus and potassium did not vary significantly after harvest of crop. This can be attributed to higher level of fertility. Due to this combination it brought about better aeration of soil moisturizer maintained on the soil and also it. Improved growth, development and height of plants and crops have been reported in the presence of optimal nitrogen. Similar result was found by Somashekar *et al.* (2015).

5.4 Relative economics

The maximum economy obtained from treatment that is seed rate of $40 \text{ kg ha}^{-1} + 120 \text{ kg N ha}^{-1}$ (S_2N_4). The practical utility of any measure can be judged on the basis of net returns. In present study S_2N_4 got more net returns than the rest of the treatments. Similar result was found by Ram and Singh (2001), Singh *et al.* (2005), Banjare and Banjara (2014), Somashekar *et al.* (2015).

5.5 Effect on fruit tree component

During the period of experimentation height of the custard apple tree and its girth, stem, canopy and the fruit yield increased. It evinces the positive response of horti-pastoral system on custard apple. This fruit is highly perishable in nature with short shelf life of 2 to 3 days under ambient conditions therefore, should be marketed immediately after harvest. Custard apple yield obtained was 836.7 kg ha^{-1} and gross income from fruit tree component was Rs.33468 kg ha^{-1} . The higher net returns and BCR with that treatment was due to more yield and moderate cost of cultivations.

SUMMARY AND CONCLUSION

In this chapter an attempt has been made to summarize the results presented in the chapter experimental findings, and also to draw valid conclusion based on the significant findings of the present investigation entitled “**Effect of seed rate and nitrogen levels on fodder sorghum under custard apple (*Annona Squamosa* L.) based horti-pastoral system**” was conducted during rainy (*kharif*) season of 2016 at Agricultural Research Farm, Rajiv Gandhi South Campus, Barkaccha (BHU), Mirzapur with the following objectives:

- To study the effect of varied seed rate and nitrogen levels on growth and yield of fodder sorghum under custard apple based horti-pastoral system.
- To study the economics of the treatments.

The experimental area falls under semi-arid to sub-humid climate and the experiment was laid out under rainfed situation and the rainfall received during the crop season was 179.87 mm. The soil of the experimental field was sandy loam in texture, well drained with pH 5.4, low in organic carbon (0.27%), available nitrogen (183.67 kg ha⁻¹), phosphorus (16.76 kg ha⁻¹) and potassium (183.25 kg ha⁻¹). Factorial Experimental was laid out in Randomized Complete Block Design with three replications in custard apple based horti-pastoral system. The treatments comprised combinations of three seed rates (S₁: 30 kg ha⁻¹, S₂: 40 kg ha⁻¹ and S₃: 50 kg ha⁻¹) and four nitrogen levels (N₁: control, N₂: 40 kg ha⁻¹, N₃: 80 kg ha⁻¹ and N₄: 120 kg ha⁻¹). Fodder sorghum (variety- MFSH- 4 / RASEELA) was taken as a test crop. Half dose of the nitrogen was applied as basal and remaining half dose was applied one month after sowing as top dressing as per treatments. The entire phosphorus and potassium was applied as basal. Urea, di ammonium Phosphate (DAP) and muriate of potash (MOP) were used as sources of nitrogen, phosphorus and potassium, respectively. The seeds were sown directly with the help of *kudal* at a distance of 30 × 5 cm. The experiment was carried out in a ten years old custard apple trees planted at 5 × 5 m spacing.

Crop response to the treatments were measured in term of various quantitative indices, viz., initial plant population, final plant population, plant height, number of leaves, number of nodes, number of internodes, leaf area index, shoot fresh weight and dry weight, and root fresh weight and dry weight were recorded at different growth stages of fodder sorghum under horti-pastoral system. Green fodder and dry fodder yield per hectare were recorded from net plot of each treatment at harvest and converted into kg ha^{-1} . Finally the comparative economics of various treatments were calculated as per the prevailing market prices.

The observations regarding growth of fruit trees (tree height, canopy diameter, stem girth and shading effect) included under study was measured at sowing, 40 DAS and harvest of fodder sorghum. At the time of test crop harvest, number of fruits per tree, fruit weight and fruit yield, number of fruit trees per hectare were also recorded from three marked sample trees from each replication.

Soil analysis of the experimental field was done by taking composite soil samples before conducting the experiment and after harvest from each treatment. The data collected during the course of experimentation were subjected to statistical analysis to draw valid conclusion. The salient features of experimental findings are summarized here under:

Effect of seed rate

- Seed rate at 50 kg ha^{-1} significantly increased the plant population (at initial and at harvest), plant height, number of node, and number of internodes per plant over 30 and 40 kg ha^{-1} seed rate at different crop growth stages. Number of functional leaves, leaf area index, dry matter production, root fresh weight and dry weight at 20, 40 DAS and harvest were significantly higher with 30 kg ha^{-1} seed rate.
- Both green and dry fodder yield increased significantly with increase in seed rate from 30 to 50 kg ha^{-1} . Maximum green and dry fodder yield were produced by highest seed rate (50 kg ha^{-1}) followed by 40 kg ha^{-1} and 30 kg ha^{-1} at harvest.

- Available N, P and K after harvest of fodder sorghum did not differ significantly due to seed rate during experimentation.

Effect of nitrogen

- Application of 120 kg N ha⁻¹ significantly increased the initial plant population, final plant population, plant height, number of functional leaves, number of nodes, internodes, leaf area index, dry matter production, root fresh weight and dry weight at 20, 40 DAS and harvest of fodder sorghum over 80, 40 kg N ha⁻¹ and control during experimentation
- Both green and dry fodder yields were significantly higher with application of 120 kg N ha⁻¹ over control, 40 and 80 kg N ha⁻¹.
- Application of 120 kg N ha⁻¹ significantly increased the available N (221.62 kg ha⁻¹) after harvest of fodder sorghum during experimentation over rest of the nitrogen levels. However, available P and K was unaffected by different nitrogen levels.

Relative economics

Maximum and minimum gross return (Rs.66945.5 ha⁻¹ and Rs.50228 ha⁻¹), net return (Rs.48807.98 ha⁻¹ and Rs.34298.2 ha⁻¹) and benefit: cost ratio (2.69 and 2.15) were recorded with seed rate of 40 kg ha⁻¹ + 120 kg N ha⁻¹ and seed rate of 30 kg ha⁻¹ + no nitrogen (control), respectively by fodder sorghum under custard apple based horti-pastoral system. However, on the basis of experimental findings, the following conclusions can be drawn:

1. The most suitable seed rate for fodder sorghum is 40 kg ha⁻¹ under custard apple based horti-pastoral system for achieving higher net returns and benefit cost ratio.
2. Optimum dose of nitrogen for fodder sorghum is 120 kg ha⁻¹ for higher net returns and benefit cost ratio under custard apple based horti-pastoral system. Since experiment was conducted only for the one season hence, results are only indicative and require further experimentation for confirmation of results.

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APPENDICES

Appendix I. Common cost of cultivation of fodder sorghum (Rs ha⁻¹)

S.No.	Operations	Input	Rate (Rs/unit)	Cost (Rs)
1	Land preparation			
	(i) One deep ploughing by soil turning plough	One tractor (35 HP) for 3 hrs	450 /hr	1350
	(ii) Harrowing and planking	One tractor (35 HP) for 2 hrs	400/hr	800
2	Layout	4 man days	180/ man days	720
3	Seed and sowing	10 man days	180/ man days	1800
4	Fertilizer application as basal	2 man days	180/ man days	360
5	Thinning	4 man days	180/ man days	720
6	Harvesting	4 man days	180/ man days	720
7	Harvesting of fruit	4 man days	180/ man days	720
8	Land revenue	For 6 months	120 annum ⁻¹	60
9	Interest on working capital	For 6 months	14% annum ⁻¹	1016
Total				8266

Appendix II: Cost of cultivation treatment wise

Treatment	Man days	Cost of man day ⁻¹ (180)	Fertilizer dose (kg ha ⁻¹)			Seed rate (kg ha ⁻¹)	Cost of fertilizer (Rs ha ⁻¹)			Cost of seed rate (Rs ha ⁻¹)	Treatment cost (Rs ha ⁻¹)	Total cost* (Rs ha ⁻¹)
			Urea	DAP	MOP		Urea	DAP	MOP			
S ₁ N ₁	2	360	-	130.40	66.66	30	-	3255.00	1198.80	2850	7663.80	15929.80
S ₁ N ₂	2	360	36.02	130.40	66.66	30	216.12	3255.00	1198.80	2850	7879.92	16145.92
S ₁ N ₃	2	360	122.80	130.40	66.66	30	736.92	3255.00	1198.80	2850	8400.72	16666.72
S ₁ N ₄	2	360	209.60	130.40	66.66	30	1257.72	3255.00	1198.80	2850	8921.52	17187.52
S ₂ N ₁	2	360	-	130.40	66.66	40	-	3255.00	1198.80	3800	8613.80	16879.80
S ₂ N ₂	2	360	36.02	130.40	66.66	40	216.12	3255.00	1198.80	3800	8829.92	17095.92
S ₂ N ₃	2	360	122.80	130.40	66.66	40	736.92	3255.00	1198.80	3800	9350.72	17616.72
S ₂ N ₄	2	360	209.60	130.40	66.66	40	1257.72	3255.00	1198.80	3800	9871.52	18137.52
S ₃ N ₁	2	360	-	130.40	66.66	50	-	3255.00	1198.80	4750	9563.80	17829.80
S ₃ N ₂	2	360	36.02	130.40	66.66	50	216.12	3255.00	1198.80	4750	9779.92	18045.92
S ₃ N ₃	2	360	122.80	130.40	66.66	50	736.92	3255.00	1198.80	4750	10300.72	18566.72
S ₃ N ₄	2	360	209.60	130.40	66.66	50	1257.72	3255.00	1198.80	4750	10821.25	19087.52

*common cost of cultivation = Rs.8266 ha⁻¹

S₁- 30 kg ha⁻¹

S₂ – 40 kg ha⁻¹

S₃ – 50 kg ha⁻¹

N₁ - 0 kg ha⁻¹

N₂ - 40 kg ha⁻¹

N₃ - 80 kg ha⁻¹

N₄ - 120 kg ha⁻¹

S – Seed rate, N – Nitrogen

Urea- @ Rs 6 kg⁻¹, DAP- @ Rs 25 kg⁻¹, MOP- @ Rs 18 kg⁻¹