“EFFECT OF VARIETIES AND FERTILITY LEVELS ON GROWTH AND YIELD OF GREEN GRAM (Vigna radiata L.) IN CUSTARD APPLE (Annona squamosa L.) BASED AGRI-HORTI SYSTEM UNDER RAINFED CONDITION”

THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Master of Science (Agriculture) in Agroforestry

Submitted by Lekhi Ram Choudhary

Supervisor Dr. M.K. Singh Co-Supervisor Dr. Rajesh Kumar

DEPARTMENT OF AGRONOMY
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I.D. No. AGF-10177 2012 Enrolment No. 323320
To,
The Registrar
Banaras Hindu University
Varanasi-221005. India

Through:     The Head
Department of Agronomy
Institute of Agricultural Sciences
Banaras Hindu University,
Varanasi-221005.

Dear Sir,

I have great pleasure in forwarding the thesis entitled “Effect of varieties and Fertility levels on growth and yield of green gram (Vigna radiata L.) in custard apple (Annona squamosa L.) based agri-horti system under rainfed condition” submitted by Mr. Lekh Ram Choudhary, Id. No. AGF-10177, in partial fulfilment 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 the basis of this thesis, to the best of my knowledge are original and genuine and no part of the work has been submitted for any other degree or dissertation.

Thanking you.

Yours faithfully

FORWARDED:

(M. K. Singh)
Supervisor
“EFFECT OF VARIETIES AND FERTILITY LEVELS ON GROWTH AND YIELD OF GREEN GRAM (Vigna radiata L.) IN CUSTARD APPLE (Annona squamosa L.) BASED AGRI-HORTI SYSTEM UNDER RAINFED CONDITION”

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At the outset, being the student of this great Institute, I bow my head with great reverence to the lotus feet of Mahamana Pandit Madan Mohan Malviya Ji, the founder of the Banaras Hindu University, whose everlasting desire was to serve mankind. I am fortunate to perceive the prodigious path to tread upon precisely through precious guidance in this university.

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et al. : and others
@ : at the rate of
cm : Centimeter
RDF : Recommended Dose of Fertilizer
cv. : Cultivar
DAS : Days After Sowing
d.f. : degree of freedom
°C : degree Celsius
Fig. : Figure
g : Gram
ha : Hectare
Kg : Kilogram
m : Meter
mg : Milligram
Mha : million hectares
mm : Millimeter
N : Nitrogen
P : Phosphorus
K : Potassium
Viz : Namely
% : Percentage
SEm± : Standard error Mean
i.e : that is
dSm⁻¹ : Deci Siemens meter⁻¹
NS : Non Significant
Max. : Maximum
Min. : Minimum
q : Quintal
t : Tonne
PSB : Phosphate Solublizing Bacteria
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INTRODUCTION

Agroforestry system with judicious mixing of crop, tree and grasses meet all basic requirements of mankind and his livestock (Singh, 1987). Agroforestry is a collective name for land-use systems and technologies, where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land management unit as agricultural crops and/or animals, either in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between the different components (ICRAF, 1993). The area under agroforestry in India is about 7.4 mha (Zomer et al., 2007.)

Agri-horti system is one of the important components of agroforestry in which the integration of fruit crops in croplands is practiced. Aonla, ber, guava, custard apple, citrus etc. are major promising fruit crop suitable for agri-horti system. Fruit crops are first preference of farmers under agroforestry system on account of short gestation period, regular income, risk cover and aesthetic value (Anonymous, 2000). Agri-horti system is an improved indigenous cropping system in India for full utilization of the growing season and markedly increasing the return per unit area per unit time.

Custard apple (*Annona squamosa* L.) is distributed throughout the tropics and is pre-eminently a desert fruit, normally eaten fresh. The vitamin C content is appreciable (35-42 mg/100 g). The nutrient value of thiamine, potassium and dietary fiber is also significant. The tree is a good source of
firewood. Green fruits, seeds and leaves have effective vermicidal 
and insecticidal properties. Leaves, shoots, bark and roots have 
been reported to have medicinal properties (Morton, 1987). The 
unripe fruit is astringent, and the root is a drastic purgative. It 
can be planted as a shade tree and also suitable for growing 
with short duration arable crops.

Green gram is an important pulse crop having high 
nutritive value. Its seed contains 24.2% protein, 1.3 % fat and 
60.4 % carbohydrate. It is a short duration crop and can be 
grown twice a year i.e. in spring and autumn seasons. The 
average yield is quite low which requires attention of the crop 
experts. Among various factors, judicious use of fertilizer is of 
prime importance. It is evident from the literature that 
application of major nutrients, i.e. NPK improved green gram 
indicate that the total pulse production is 17.29 million tons 
from 25.51 million ha area which is all times high and is the 
only exception year. The total area and production under green 
gram in India (2010-11) was about 3.44 mha and 1.20 mt and 
productivity was 351Kg ha\(^{-1}\) (ICAR Vision, 2030).

Green gram (*Vigna radiata* (L.) Wilczek) is an important 
pulse crop grown extensively in India under varying soil types 
and climatic conditions. Seed inoculation with effective and 
competitive *Rhizobium* is a recommended agronomic practice for 
pulse production technology. The phosphorus (P) present in soil 
becomes unavailable to plants due to its chemical fixation, thus 
favouring inoculation with phosphate solubilizing bacteria (PSB). 
PSB solubilize the insoluble phosphates in soil, making P 
available to plant. Thus combined inoculation with microbial
biofertilizers (R + PSB) which are eco-friendly, low cost and non-bulky input, can play a significant role in plant nutrition and in increasing grain yield (Singh and Pareek, 2003).

The improvement of soil fertility is one of the most common strategies to increase agricultural production. The biological nitrogen fixation is very important in enhancing the soil fertility. In addition to biological nitrogen fixation, Phosphate solubilization is equally important. Phosphorus (P) is major essential macronutrients for biological growth and development. Microorganisms offer a biological rescue system capable of solubilizing the insoluble inorganic P of soil and make it available to the plants (Rodriguez, 2006, Chen, 2006).

Farmers have a wrong notion that green gram, being legume crop does not need any nutrient and usually grow it on the marginal lands without applying any fertilizer. This seems to be an important reason for low productivity in the country (Hussain, 1983). The beneficial effects on the yield of different crops have been noticed from the soil application of the deficient macronutrient (Khan et al., 2004), and the poor performance of fertilizer phosphorus is one of the major causes depressing the productivity of the crops. Hence, the effect of phosphorus on root development is well established (Hossain and Hamid, 2007). Addition of N and P fertilizer enhances root development, which improves the supply of other nutrients and water to the growing parts of the plants, resulting in an increased photosynthetic area and thereby more dry matter accumulation. The application of phosphorus to green gram has been reported to increase dry matter at harvest, number of pods plant⁻¹, grains pod⁻¹, 1000 grain weight, seed yield and total biomass (Mitra et al., 1999).
Nitrogen and phosphorus alone or in combination play a remarkable role in increasing yield and improving the quality of mung bean. Application of small amount of nitrogen as a starter dose has a beneficial effect on crop yield and quality as reported by Sandhu et al. (1978). Similarly phosphorus plays a vital role in the formation and translocation of carbohydrates, root development, crop maturation and resistance to disease pathogens. Thus increase the green gram yield and improves its quality (Arya and Kalara, 1988). Application of nitrogen in combination with phosphorus to green gram also increases its yield and yield components (Hussain, 1994) while nitrogen uptake and protein content of green gram increase with increasing rate of applied phosphorus (Dewangan, 1992). Hence, there is a dire need to investigate the suitable levels of nitrogen and phosphorus for obtaining higher yield and quality of green gram. The Rhizobium + PSB inoculation had positive effect on grain yield of black gram (Vigna mungo L.) which was slightly higher than obtained with either Rhizobium or PSB separately. (Hussain et al., 2011).

Keeping these facts into consideration the present investigation entitled “Effect of different varieties and fertility levels on growth, yield of green gram (Vigna radiata L.) in custard apple (Annona squamosa L.) based agri-horti system under rainfed condition” was conducted with following objectives:

1. To find out the effect of varieties and fertility levels on growth attributes of green gram under custard apple based agri- horti system.
2. To find out the effect of varieties and fertility levels on yield attributes, yield and of green gram under custard apple based agri-horti system.

3. To work out the economics of different treatments.
REVIEW OF LITERATURE

An attempt has been made in this chapter to review the literature embracing the relevant references related to different aspects of present investigation in the country and abroad. This information is mostly from Indian situation in which the experiment was conducted. However, some international literatures have also been cited in order to get useful information regarding the present investigation under the appropriate heads.

2.1 Effect of agri-horti system on crop

Pandey et al. (1998) evaluated the effect of *Rhizobium* inoculation and fertilizer on the yield and yield components of three green gram cultivars (Pusa 105, Pusa 9531 and Pant Mung 2) alone and under poplar. The yield and yield components of green gram were found significantly higher in sole cropping than in agroforestry.

Korwar et al. (1999) reported that grain yields of green gram and black gram were higher under the lower tree density than when monocropped or grown under the higher tree density, whereas cowpea yield was lower under the trees at both densities than when monocropped. The green gram equivalent yield and net returns were highest with black gram under low tree density, followed by green gram.

Thakur et al., (2002) studied the effects of different canopy management treatments in 5-year old *Morus alba* trees on growth and yield potential of urd bean and pea. They reported that growth and yield attributes as well as followed by plants under least shade (75% crown removal). The values decreased
with increasing shade (less transmission) in both urd and pea. Better growth and yield was observed on northern aspect than southern aspect. Yield increased with increasing light transmission through tree canopy.

Mohanty *et al.* (2004) studied four tree sp. (*Casuarina equisetifolia, Eucalyptus* hybrid, *Dalbergia sissoo* and *Tectona grandis*) planted in rows at with row spacing of 5m to study the effect of crops (ragi, sesame, black gram, and cowpea) sown in the alleys with recommended fertilizer application. They reported that association of tree adversely affected the grain production of crops. Among the field crops, ragi with a mean grain yields of 6.85 q ha\(^{-1}\) emerged as the most stable crop with least reduction in yield (21\%). It is revealed that the overall performance of intercrops was 31% lower than the sole crop yield.

Lal and Sharma (2004) concluded that litchi (*Litchi chinensis*) plantation based agri-horti system can be raised on degraded gravelly riverbed land in Doon valley of erstwhile Uttar Pradesh with cowpea, okra, sesame, black gram and pigeon pea, as intercrops during the *Kharif* season and toria during the *rabi* season. The highest net profit of Rs. 4554 was obtained from okra-toria cropping system followed by cowpea-toria (Rs. 1270) and black gram-toria (Rs. 779) cropping systems with benefit: cost ratio of 1.27, 1.08 and 1.05, respectively. The plant growth character of litchi was not influenced by any intercrop.

Datta *et al.* (2007) studied the multipurpose tree species (MPTs) in an agroforestry system under subtropical humid climate in Northeast India. Direct seeded upland rice, groundnut and sesame were grown during the initial period upto 8 year of
tree establishment which resulted reduction in crop productivity as compared to open space.

Handa (2007) investigated that the pruning intensity and its effect on the growth performance of tree species [[*Hardwickia binata*, *Anogeissus pendula* (*A. acuminata*) and *A. latifolia*]] and yield of black gram. The pruning was initiated for the first time after 8 years of establishment of the tree species. There were four pruning treatments (10, 25, 50 and 75 per cent) with 10 per cent pruning as control. Black gram was used as intercrop during the *Kharif* season. Crop data revealed that maximum grain (141 Kg ha⁻¹) and straw yield (233 Kg ha⁻¹) were recorded with *H. binata* at 75 per cent pruning intensity. No adverse effect was observed even 75 per cent pruning on tree growth while intercrop yield was maximum.

Ram and Kumar (2007) reported that the introduction of *S. hamata* in natural pasture under *Annona squamosa* trees resulted in significantly higher total crude protein yields (255.9, 311.7 and 305.1 Kg ha⁻¹) than *S. scabra* in first, second and third years, respectively.

Shukla et al. (2008) reported that fruit species, *Annona squamosa* were not for growing in horti-pastural system in rangelands because of their poor establishment and survival. While Mohanty et al. (1992) observed that tree association affected the crop yield negatively and *Eucalyptus* hybrid reduced the alley crop yield by 17.2 to 41 per cent.

Beg and Singh (2009) reported that the interaction effect due to dual inoculation with *Rhizobium* and PSB under moderate fertility level (20 Kg N and 45 Kg P₂O₅ ha⁻¹) proved beneficial for boosting seed yield (1182 Kg ha⁻¹), and gave
maximum net income (Rs 21941 ha\(^{-1}\)) and benefit: cost ratio (2.10).

**2.2 Effect of varieties**

**2.2.1 On growth attributes**

Sahu (1986) reported that Pusa Baisakhi, K 851 and Type 1 which were at par, took significantly lesser time to flower compared to Selection 9, respect to days taken to maturity, Pusa Baisakhi, Type 1 and K 851 which were at par, matured earlier than Selection 9. Kalita and Shas (1988) studied 19 green gram cultivars at Anand (Gujrat) and observed that total reproductive organs (buds, flowers and pods) shedding was lowest in A-57-7 (60.1%) and highest in Gujrat-2 (70.6%).

Mitra *et al.* (1999) A field experiment was conducted during the *Kharif* (rainy) seasons of 1996 and 1997 to study the effects of cultivar, rock phosphate and phosphate solubilizing bacteria on growth and yield of green gram (*Vigna radiate* L.) in acid soils of Tripura. Green gram cv. GM-9002 had greater dry matter at harvest, number of pods plant\(^{-1}\), grains pod\(^{-1}\), 1000-seed weight, seed yield and total biomass yield than cv. UPM 79-12 or MH-309.

Singh *et al.* (2005) observed the response of different green gram genotypes (SML 134, SML 357 and SML 688) on growth. The results showed significantly higher plant and higher leaf area in SML 134 than SML 357 which results in more dry matter accumulation in SML 134.

Vijaylaxmi and Bhattachary (2006) reported that twenty five green gram genotypes were involved in field trials to elucidate the effect of different growth and developmental parameters in different plant parts at various crop growth
Review of Literature

stages. Different growth and developmental parameters viz., RGRs of plant parts, NAR, LAD and SLW were estimated at flowering, podding, 20 days after podding and at maturity. It was concluded that genotypic variability exists in green gram for growth parameters viz., relative growth rates of different plant parts, net assimilation rate, leaf area duration, and specific leaf weight at various crop growth stages and yield is determined positively by the shoot relative growth rate during 20 days after podding and maturity, and negatively through dry matter partitioned in leaf and stem during these growth stages.

2.2.2 On yield and yield attributes

Roychowdhury and Dasgupta (2002) Nineteen cultivars of green gram were grown in West Bengal, India under two environments, i.e. environment 1 (high lands with high rainfall; kharif; sowing in May) and environment 2 (low lands under irrigated conditions; Rabi sowing in November). Sixteen characters were studied, and correlation and path analyses were carried out to identify the important yield components. The number of pods plant$^{-1}$, pods main$^{-1}$ stem, pods branch$^{-1}$, and seeds plant$^{-1}$, and 100-grain weight were significantly and positively correlated with grain yield plant$^{-1}$. The path coefficient analysis of grain yield plant$^{-1}$ indicated that the number of pods plant$^{-1}$ and grain plant$^{-1}$, and 100-grain weight had highly positive direct effects on grain yield.

Hossain and Solaiman (2004) The effects of Rhizobium inoculation on the nodulation, plant growth, yield attributes, grain and straw yields, and seed protein content of six green gram (Vigna radiate L.) cultivars were investigated. The green gram cultivars were BARI Mung-2, BARI Mung-3, BARI Mung-4,
BARI Mung-5, BINA Moog-2 and BU Mung-1. Among the cultivars, BARI Mung-4 performed the best in all aspects showing the highest grain yield of 1135 Kg ha\(^{-1}\). *Rhizobium* strain TAL169 did better than TAL441 in most of the studied parameters. The number of pods plant\(^{-1}\) and 1000-grain weight had positive correlations with grain yield ha\(^{-1}\). It was concluded that BARI Mung-4 in combination with TAL169 performed the best in terms of nodulation, plant growth, grain and straw yields, and grain protein content.

Bhati *et al.* (2005) Studies were conducted from 2000 to 2003 to evaluate the effects of cultivars and nutrient management strategies on the productivity of different *kharif* legumes (green gram, moth bean and cluster bean) in the arid region of Rajasthan, India. The experiment with green gram showed that K-851 gave better yield than Asha and the local cultivar. In another experiment, green gram cv. PDM-54 showed 56.9% higher grain yield and 13.7% higher grain yield than the local cultivar.

Singh and Tripathi (2005) A field experiment was conducted in Jodhpur, Rajasthan, India, during the *kharif* seasons of 2003 and 2004, to evaluate the effects of cultivar (K-851 and RMG-62) as well as nitrogen (0 and 20 Kg ha\(^{-1}\)) and phosphorus levels (0, 20 and 40 Kg ha\(^{-1}\)) on the productivity of green gram. K-851 produced significantly higher values for grain and straw yields as well as yield attributes (plant height, pods plant\(^{-1}\), grain pod\(^{-1}\) and 1000-grain weight) compared with RMG-62.

Naeem *et al.* (2006) a field experiment was carried out to determine the effect of organic manures and inorganic fertilizers
on growth and yield of green gram (*Vigna radiata* L.). Experiment comprised of two varieties (NM-98 & M-1) and four fertility levels as NPK @ 25 -50 - 50 Kg ha\(^{-1}\), poultry manure @ 3.5 t ha\(^{-1}\), FYM @ 5 t ha\(^{-1}\) and Bio-fertilizer @ 8 g Kg\(^{-1}\) grain. NPK fertilizers and organic manures were applied at the time of seed bed preparation. Green gram grain yield was recorded highest (1104 Kg ha\(^{-1}\)) with the application of the inorganic fertilizers (NPK @ 25 - 50 - 50 Kg ha\(^{-1}\)). Among organic nutrient a source, poultry manure @ 3.5 t ha\(^{-1}\) was found the best followed by FYM @ 5 t ha\(^{-1}\). Both varieties were equal in grain yield. Numbers of pods, number of grains pod\(^{-1}\) and 1000 grain weight were also almost higher in inorganic fertilizer treatment.

Bhuiyan and Mian (2007) Experiments with or without *Brady rhizobium* was carried out with five green gram varieties at Bangladesh Agricultural University Farm during *Kharif*-I 2001 and *Kharif*-I 2002 seasons to observe nodulation, biomass production and yield of green gram. Significant influences of the green gram varieties were observed on nodulation, biomass production and yield. BARI Mung-2 produced the highest nodule number, nodule weight, shoot weight, grain yield (1.03 t ha\(^{-1}\) in 2001 and 0.78 t ha\(^{-1}\) in 2002) and stover yield (2.24 t ha\(^{-1}\) in 2001 and 2.01 t ha\(^{-1}\) in 2002). Considering nodulation, biomass production and grain and straw yields, BARI Mung-2 was found as the best variety. BARI Mung-5 produced the second highest grain yield followed by BARI Mung-4 and BINA Mung-2, and the lowest grain yield was observed in Barisal local.
2.3 Effect of chemical fertilizers

2.3.1 On plant height

Ardeshana (1993) reported that the application of 30 Kg N ha\(^{-1}\) + 40 Kg P\(_2\)O\(_5\) ha\(^{-1}\) producing significantly higher growth characters, like plant height, branches plant\(^{-1}\), root nodules, and pods plant\(^{-1}\) as compared to the control. Venugopal (1973) also found similar results.

Reddy and Ahlawat (1998) in an experiment conducted at New Delhi on sandy loam soil observed that significant increase in plant height, dry matter production, leaf area index and root nodule mass of chickpea with application of 18 Kg N + 46 Kg P\(_2\)O\(_5\) ha\(^{-1}\) over control.

Ram and Dixit (2001) worked on the effect of P application (0, 20, 40 and 60 Kg P\(_2\)O\(_5\) ha\(^{-1}\) ) on green gram cv. ‘K 851’ found that increasing doses of phosphorus produced the tallest plants, higher number of branches plant\(^{-1}\), increased dry matter accumulation and number of leaves plant\(^{-1}\).

2.3.2 On number of trifoliate leaves plant\(^{-1}\)

Chaturvedi et al. (2004) evaluated the four phosphorus levels (0, 20, 40 and 60 Kg ha\(^{-1}\) ) in relation to their effect on the growth of green gram cv. ‘K 851’ and found that increase in phosphorus levels up to 60 Kg ha\(^{-1}\) had a significant effect on the growth attributes of green gram \(\nuiz.,\) plant height, number of branches plant\(^{-1}\), number of trifoliate leaves plant\(^{-1}\), leaf area index, dry matter accumulation plant\(^{-1}\), crop growth rate, relative growth rate and net assimilation rate.

2.3.3 On number of branches plant\(^{-1}\)

Shukla and Dixit (1996) worked on the effect of phosphorus levels (0, 20, 40 and 60 Kg ha\(^{-1}\) ) on summer green
gram observed that the plant height, number of primary branches plant\(^{-1}\), and dry matter accumulation were significantly increased by increasing rate of phosphorus up to the highest level.

### 2.3.4 On dry matter accumulation (g plant\(^{-1}\))

According to Yakadri et al. (2004), application of fertilizers showed a benefit on dry matter production of green gram under red sandy loam soil at Rajendranagar, Hyderabad and recorded significantly higher dry matter production with 20 Kg N + 60 Kg P\(_2\)O\(_5\) ha\(^{-1}\) as compared to the control.

### 2.3.5 On nodulation

On loamy sand at Jobner (Rajasthan), Singh and Pareek (2003) revealed that the plant height, branches plant\(^{-1}\), number of nodules plant\(^{-1}\) and nodules weight plant\(^{-1}\) of green gram variety ‘RMG-62’ significantly increased up to 30 Kg P\(_2\)O\(_5\) over 15 Kg P\(_2\)O\(_5\) ha\(^{-1}\) and the control.

Baboo and Mishra (2004) observed that plant height and number of leaves plant\(^{-1}\) of cowpea significantly increased with each increase in N levels. Obviously, dry matter accumulation and number of nodules markedly increased with nodulation plus 20 Kg N ha\(^{-1}\) over their individual application. Though each increase in P level up to 90 Kg ha\(^{-1}\) had marked increase in growth parameters over the control.

### 2.3.6 On number of pods plant\(^{-1}\)

Yakadri et al. (2002) reported that 60 Kg N + 60 Kg P\(_2\)O\(_5\) ha\(^{-1}\) produced significantly higher growth attributes like number of leaves plant\(^{-1}\), number of pods plant\(^{-1}\) and grains pod\(^{-1}\) of green gram.
Yadav (2004) studied to incremental levels of phosphorus (0, 20 and 40 Kg ha\(^{-1}\)) and sulphur (0, 20, 40 and 60 Kg ha\(^{-1}\)) on the growth and yield of green gram cv. ‘RMG-62’ resulted in increased plant height, number of branches, number of pods plant\(^{-1}\) and biological yield with increasing rates of phosphorus and sulphur each up to 40 Kg ha\(^{-1}\).

2.3.7 On number of grains pod\(^{-1}\)

On sandy-loam soil at Faizabad (Uttar Pradesh), Shukla and Dixit (1996) reported that number of pods plant\(^{-1}\) and number of grain pod\(^{-1}\) was significantly increased with application of P\(_2\)O\(_5\) 40 Kg ha\(^{-1}\). Higher dry matter accumulation resulted in higher grain yield at higher dose of phosphorus. The results confirmed the findings of Akhtar et al. (1986) and Patel and Parmar (1986).

Reddy and Swamy (2000) studied the effect of 3 levels of phosphorus (0, 13.1 and 26.2 Kg P\(_2\)O\(_5\) ha\(^{-1}\)) on green gram. They observed that with an increase in phosphorus level from 0 to 26.2 Kg P\(_2\)O\(_5\) ha\(^{-1}\), yield attributes over the control. But grains pod\(^{-1}\) at 26.2 Kg P\(_2\)O\(_5\) was comparable with that of 13.1 Kg P\(_2\)O\(_5\) ha\(^{-1}\). Phosphorus content in straw and grain increased significantly by the application of 26.2 Kg P\(_2\)O\(_5\) ha\(^{-1}\).

2.3.8 On 1000-grain weight

Shukla and Dixit (1996) noted that application of phosphorus significantly increased the number of grain pod\(^{-1}\), number pods plant\(^{-1}\) and test weight with 40 Kg ha\(^{-1}\). A linear increase in grain yield was recorded up to 60 Kg P\(_2\)O\(_5\) ha\(^{-1}\). However, grain yield significantly increased up to 40 Kg P\(_2\)O\(_5\) ha\(^{-1}\).
Singh and Pareek (2003) reported that yield of green gram variety ‘RMG-62’ significantly increased yield attributes like, number of pods plant⁻¹, number of grains pod⁻¹, test weight and grain yield with application of phosphorus up to 45 Kg P₂O₅ over all the lower levels of phosphorus. Similar results were also reported due to application of 40 Kg P₂O₅ ha⁻¹ by Shukla and Dixit (1996) and 50 Kg P₂O₅ ha⁻¹ by Sharma and Singh (1997).

Chaudhary et al. (2003) investigating the effects of Phosphorus application at 20, 40 and 60 P₂O₅ Kg ha⁻¹ on the yield components of green gram cv. ‘K 851’ showed positive effects of P₂O₅ application on pods plant⁻¹, grains pod⁻¹ and test weight.

2.3.9 On grain yield

Saxena et al. (1996) reported that the phosphorus @ 60 Kg and potassium @ 20 Kg ha⁻¹ producing significantly higher grain yield and harvest index.

Yakadri et al. (2002) investigating the effect of incremental doses of nitrogen (20, 40 and 60 N Kg ha⁻¹) and phosphorus (40 and 60 P₂O₅ Kg ha⁻¹) on growth and yield of green gram (cv. ML-267) reported that the application of nitrogen @ 20 Kg and phosphorus @ 60 Kg ha⁻¹ caused significant increase in number of pods plant⁻¹ and grain yield.

Malik (2003) studied effect of varying levels of nitrogen (0, 25 and 50 Kg ha⁻¹) and phosphorus (0, 50, 75 and 100 Kg ha⁻¹) on the yield and quality of green gram (Vigna radiata L.) cultivar NM-98 during the year 2001. Various growth and yield components were significantly affected by varying levels of nitrogen and phosphorus. A fertilizer combination of 25-75 N-P₂O₅ Kg ha⁻¹ resulted in maximum grain yield (1112.96 Kg ha⁻¹).
Satish et al. (2003) on alkaline, sandy loam soil reported that the application of 60 and 40 P$_2$O$_5$ Kg ha$^{-1}$ being at par with each other, however, produced significantly higher number of pods plant$^{-1}$, grains pod$^{-1}$, grain yield of green gram over 20 P$_2$O$_5$ Kg ha$^{-1}$ and the control. Singh et al. (2001) also reported the beneficial effect of phosphorus application on the grain yield of green gram.

Yadav (2004) conducted an experiment on the effect of phosphorus (0, 20 and 40 Kg ha$^{-1}$) and sulphur (0, 20, 40 and 60 Kg ha$^{-1}$) application on the growth and yield of green gram cv. “RMG-62” and reported that number of grains pod$^{-1}$, test weight, grain yield and biological yield were increased with increasing rates of phosphorus and sulphur each up to 40 Kg ha$^{-1}$.

On sandy loam in soil texture with pH 7.5 at Baldanya, Murshidabad (W.B.), Malay et al. (2006) reported that yield of green gram increased under higher fertility levels due to improvement in yield attributes like number of productive pods plant$^{-1}$, grains pod$^{-1}$ and grain weight. Maximum yield was recorded at fertility level of 20, 60, 40 Kg ha$^{-1}$ N, P$_2$O$_5$ and K$_2$O. Significant yield increase with the application of 20 Kg N and 60 Kg P$_2$O$_5$ ha$^{-1}$ was also reported by Sharma et al. (2003).

**2.3.10 On straw yield**

Kumar et al. (2002) conducted a field experiment at Hisar (Haryana) and observed that progressive increase in levels of P up to 40 Kg ha$^{-1}$ significantly increased the straw yield of green gram.

Singh and Pareek (2003) reported that straw yield of green gram significantly increased up to 30 Kg P$_2$O$_5$ ha$^{-1}$. 
2.3.11 On nutrient contents and their uptake

A field experiment conducted by Rao et al. (1993) to find out response of green gram cultivars to levels of phosphorus in sandy loam soil of Bapatla (Andhra Pradesh) revealed that the maximum uptake of P was recorded with ‘Pusa Baisakhi’ followed by ‘LGG 407’, ‘ML 267’ and ‘LGG 410’. In all the varieties, significant increase in P uptake was recorded at 25 and 50 Kg P₂O₅ ha⁻¹ over the control. Bhalu et al. (1995) observed that N and P uptake by both grain and straw of black gram significantly increased with 20 Kg N than 10 Kg N ha⁻¹. Phosphorus application at the levels of 40 and 60 Kg P₂O₅ were statistically at par with each other in respect of N and P uptake by grain and straw, but significantly higher than that of 20 Kg P₂O₅ ha⁻¹.

Shukla and Dixit (1996) reported that nitrogen and phosphorus uptake and protein content of green gram seeds significantly increased due to application of 20, 40 and 60 Kg P₂O₅ ha⁻¹ over the control. Reddy and Ahlawat (1998) observed that application of 18 Kg N + 46 Kg P₂O₅ ha⁻¹ in chikpea significantly increased the N and P uptake and protein yield over lower doses and the control.

Shahi et al. (2002) conducted a field experiment at Allahabad, Uttar Pradesh during Kharif season and found that significantly increased in protein content (21.22 per cent) of green gram by the application of 20 Kg P₂O₅ ha⁻¹ and Rhizobium inoculation over uninoculated treatment.

On red sandy loam soil at Rajendranagar, Yakadri et al. (2004) reported that green gram removed more nitrogen than phosphorus. Fertility treatment 20 Kg N + 60 Kg P₂O₅ showed
maximum N and P uptake and differed significantly from 20 Kg N + 40 Kg P_2O_5, 40 Kg N + 60 Kg P_2O_5, 60 Kg N + 40 Kg P_2O_5 and 60 Kg N + 60 Kg P_2O_5 but being at par with 40 Kg N + 40 Kg P_2O_5 ha^{-1}.

On silty-clay loam soil at Regional Research Satation and Faculty of Agriculture, SKUAST-K, Wadura, Baramulla, Kashmir, Beg and Singh (2009) observed that the increase in amount of N and P removal in green gram was noticed with application of 30 Kg N and 60 Kg P_2O_5 (124.1 Kg N and 13.8 Kg P_2O_5 ha^{-1}), over no N and P application (64.3 Kg N and 5.5 P ha^{-1}, respectively).

### 2.4 Effect of *Rhizobium* and PSB on green gram

*Rhizobium* is the general name given to a phylogenetically diverse group of soil bacteria that form nitrogen fixing symbiosis with leguminous plants. This symbiosis is among the most important ecological interactions to humans and ecosystems. It is estimated to globally produce as much nitrogen as fixed by commercial fertilizer production (Gordon *et al.*, 2001), and it represents the most important nitrogen input to many ecosystem. Rhizobia are found free living in the soil and reproduce independent of the legumes. However, during the symbiosis, rhizobia and the legume plant coordinate on building a novel plant organ, called the nodule, which fixes nitrogen. Successful *Rhizobium* legume symbiosis will definitely increase the incorporation of BNF into soil ecosystems. *Rhizobium* legume symbioses are the primary source of fixed nitrogen in land based systems (Tate, 1995) and can provide well over half of the biological source of fixed nitrogen (Tate, 1995).
2.4.1 On plant height

Ashraf et al. (2003) reported that maximum plant height (69.93) was recorded in plots where seed was treated with *Rhizobium phaseoli*. Ardeshna et al., (1993) conducted a field experiment at Junagarh on clayey soil and found that *Rhizobium* inoculated plant of green gram showed significantly higher plant height.

Vijila and Jebaraj (2008) reported that seven strains of *Rhizobium* were compared for their symbiotic performance with the host legume, green gram. The rhizobial strain, VRM 3 obtained from the host grown under acid soil performed better than the other strains. This acid tolerant strain demonstrated a comparative advantage of over acid sensitive strains in their ability to nodulate and thereby promoting the growth and yield of green gram. Combined inoculation of this strain with phosphor bacteria and plant growth promoting rhizo bacteria resulted in improvement of crop yield over single inoculation under acidic soil conditions, at National Pulses Research Centre, Tamil Nadu.

Bhuiyan et al. (2008) reported positive and significant effect of *Rhizobium* inoculants on plant height of green gram. *Rhizobium* inoculants alone gave higher plant height (32.12cm) than the control.

Manke et al. (2008) the dual soil application of *Rhizobium* and vesicular arbuscular mycorrhizal fungi (VAM) showed synergistic effect on all green gram cultivars. Among the four cultivars tested, 'Vaibhav' was found host responsive to root nodulation, growth parameters and grain yield. The seed inoculation of *Rhizobium* + VAM enhanced more all the
parameters compared to the single inoculation of *Rhizobium* or VAM or 100% chemical fertilizer application.

Sethi and Adhikary (2009) reported that Effect of *Rhizobium* inoculation on vegetative growth and yield of two different leguminous crops *Arachis hypogea* and *Vigna mungo* was investigated. Inoculation of crop specific rhizobial strains increased plant biomass, nodule number, height of plant, leaf number, and flower number. The yield of *Arachis hypogea* and *Vigna radiata* due to *Rhizobium* inoculation was higher by 22% and 29%, respectively over control.

Zahir et al. (2010) reported that *Rhizobium* inoculation gave the most promising results and significantly increased the plant height of green gram. The *Rhizobium* inoculation significantly increased (23.4% over control) plant height.

**2.4.2 On number of trifoliate leaf plant**<sup>1</sup>

Srinivas and Mohammad (2002) reported that number of leaves plant<sup>-1</sup> in green gram generally increased due to seed inoculation with *Rhizobium*. Seed inoculation with *Rhizobium* significantly increased number of leaves plant<sup>-1</sup> over control (Kerni and Gupta, 1991).

Bhuiyan et al. (2008) reported that inoculated plants produced higher number of leaves (19.54) compared to uninoculated plants.

**2.4.3 On number of branches plant**<sup>-1</sup>

Ardeshna et al. (1993) conducted a field experiment at Junagarh on clayey soil and reported that *Rhizobium* inoculated plant of green gram showed significantly more number of branches plant<sup>-1</sup>.
Vijila and Jebaraj (2008) also observed slight improvement of branches plant$^{-1}$, pods plant$^{-1}$, grains pod$^{-1}$ and 1000-grain weight, due to *Rhizobium* + PSB inoculation than inoculate them separately.

Kumawat *et al.* (2010) reported that inoculation of *Rhizobium* and application of 15 Kg N + 20 Kg P$_2$O$_5$ ha$^{-1}$ significantly increased the number of branches plant$^{-1}$ of green gram.

### 2.4.4 On dry matter accumulation plant$^{-1}$

Shukla and Dixit (1996) reported that *Rhizobium* inoculation increased the dry matter accumulation significantly at all the growth stages of green gram.

Singh and Pareek (2003) reported that *Rhizobium* along with PSB inoculation in green gram significantly improved dry matter accumulation meter$^{-1}$ row length by 44.22 and 17.70 per cent, respectively at 50 DAS and at harvest over the control (no inoculation).

Bhuiyan *et al.* (2008) observed significant effect of rhizobium inoculation on shoot dry weight of green gram and recorded the highest shoot dry weight (3.29 g plant$^{-1}$).

Yadav *et al.* (2010) conducted an experiment in *Kharif* 2007 and 2008 and reported that seed inoculation of green gram with *Rhizobium* significantly increased dry weight of root 0.11g and 0.12 g and dry weight of shoot 1.86 g and 1.90 g, respectively.

### 2.4.5 On nodulation

Patra and Bhattacharya (1997) conducted a field trial on green gram and observed that when seed of green gram were inoculated with *Rhizobium* and fertilized with 25 Kg urea ha$^{-1}$ it
increased nodulation over control resulting highest number of nodules plant\(^{-1}\).

Kumar and Chandra (2003) reported that combined inoculation of \textit{Rhizobium} + VAM (\textit{Glomus caledonius}) resulted in significantly more nodule number at 30 and 50 DAS and grain yield of field grown green gram with numerical increase in plant biomass over single inoculation with either \textit{Rhizobium} or VAM in a soil of medium P status.

On sandy loam soil at Pantnagar, Chandra and Pareek (2007) reported that inoculation of green gram variety ‘Pant Mung 2’ with seed inoculation as carrier based and liquid inoculants were comparable and significantly favored the number and dry weight of root nodules in both the years, registering mean increase of 25.2 to 40.5 per cent and 47.3 to 38.7 per cent over the uninoculated control, respectively. The results are in conformity with earlier report of Gupta (2005) who found similar effectiveness of carrier based and liquid inoculants in chickpea.

Bhuiyan \textit{et al.} (2008) reported that inoculation had a significant and positive effect on the formation of nodules. Seed inoculation with \textit{Rhizobium} markedly increased number of nodules (11.25) as compared to that of the non-inoculated plants of green gram.

Yadav \textit{et al.} (2010) conducted an experiment in \textit{kharif} 2007 and 2008 and reported that seed inoculation of green gram with \textit{Rhizobium} significantly increased number of nodules 21.9 and 29 and nodules dry weight 83.5 and 55.55 g, respectively.
2.4.6 On number of pods plant$^{-1}$

Nadeem et al. (2004) reported that the number of pods plant$^{-1}$ was significantly affected by seed inoculation with *Rhizobium* in green gram: the inoculated seed produced significantly higher number of pods plant$^{-1}$ than uninoculated seed (15.65). Khan et al. (2002) reported that the number of pods plant$^{-1}$ increased with *Rhizobium* inoculation of green gram.

On sandy soil at Durgapura, Jaipur (Rajasthan), Bansal (2009) reported that pre sowing inoculation of green gram seeds with different inoculants (*Rhizobium*, PGPR and PSB) alone or in combination, significantly increased the nodulation and grain yield over the uninoculated control. Nodulation and grain yield was the highest when seeds were inoculated with *Rhizobium* + PGPR + PSB followed by *Rhizobium* + PGPR and *Rhizobium* alone, during all the three *kharif* seasons of the experimentation. In pooled analysis also showed, combined inoculation of green gram seeds with *Rhizobium* + PGPR + PSB gave the significantly highest number of nodules plant$^{-1}$ (21.0), dry weight of nodules plant$^{-1}$ (87.66 mg plant$^{-1}$) and grain yield (12.94 qha$^{-1}$). It was at par with *Rhizobium* + PGPR with grain yield 12.14 qha$^{-1}$.

Zahir et al. (2010) reported that *Rhizobium* inoculation gave the most promising results and significantly increased the number of nodules per plant. *Rhizobium* inoculation in green gram revealed 80% increase in number of nodules over the control.

Bhat et al. (2010) reported that seed inoculation with *Rhizobium* significantly increased the nodulation from 28.30 to 45.68 and 17.26 to 33.40 at flowering and at harvest stages, respectively.
Hussain (2010) a pot experiment was conducted in wire house, during spring season in the Institute of Soil and Environmental Sciences at University of Agriculture, Faisalabad to study the influence of phosphorus fertilization and *Rhizobium* inoculation on growth and yield parameters of green gram (*Vigna radiata*). A composite soil sample was collected for analysis of soil for physical and chemical properties. Phosphorus application along with *Rhizobium* inoculation increased the dry weight of nodules, roots, shoots and grains significantly. Maximum dry weights were observed where recommended and 150% of the recommended dose of phosphorus along with *Rhizobium* inoculation was applied. It was concluded that green gram crop should preferably be grown with 150% of the recommended dose of phosphorus along with *Rhizobium* inoculation under agro-ecological conditions of Faisalabad for obtaining higher yield.

Bhat *et al.* (2010) reported that inoculation of *Rhizobium* improved number of pods plant\(^{-1}\) (25.5).

**2. 4.7 On number of grains pod\(^{-1}\)**

Shukla and Dixit (1996) reported that seed inoculation of green gram with *Rhizobium* increased the number of grains pod\(^{-1}\) (6.41) in green gram.

Malik *et al.* (2002) observed that the seed inoculation of green gram with *Rhizobium* resulted in the higher number of grains pod\(^{-1}\) (12.06).

Srinivas and Mohammad (2002) reported that the seed inoculation of green gram with *Rhizobium* culture resulted higher value for number of grains pod\(^{-1}\).
Nadeem et al. (2004) observed that in green gram number of grains pod\textsuperscript{-1} was significantly affected by seed inoculation with *Rhizobium*.

### 2.4.8 On 1000-grain weight

Shukla and Dixit (1996) reported that the inoculated seeds of green gram with *Rhizobium* increased 1000-grain weight (37.64 g) of green gram.

Malik et al. (2002) reported that seed inoculation of green gram with *Rhizobium* resulted in the highest 1000 grain weight (42.27g.).

Srinivas and Mohammad (2002) reported that seed inoculation with *Rhizobium* resulted higher value for 1000-grain weight of green gram.

Nadeem et al. (2004) stated that the 1000-seed weight of green gram crop was significantly affected by seed inoculation by *Rhizobium* 46.89 g.

Yadav et al. (2007) A field experiment was carried out at Allahabad, Uttar Pradesh, India, during the *Zaid* season of 2001 to study the effects of biofertilizers (*Rhizobium* alone and in combination with phosphate solubilizing bacteria), poultry manure (at 0 and 5 t ha\textsuperscript{-1}) and P levels (50 and 75 Kg P\textsubscript{2}O\textsubscript{5} ha\textsuperscript{-1}) on nodulation and yield of green gram cv. K-851. The highest grain yield (12.49 q ha\textsuperscript{-1}), grains pod\textsuperscript{-1} (13.16), test weight (42 g) and nodule number plant\textsuperscript{-1} (35.62) were recorded with the application of Rhizobium and phosphate solubilizing bacteria + P\textsubscript{2}O\textsubscript{5} @ 75 Kg ha\textsuperscript{-1} + poultry manure @ 5 t ha\textsuperscript{-1}. 
2.4.9 On grain yield

Malik et al. (2002) reported that seed inoculation of green gram with *Rhizobium* recorded in higher grain yield (1158 Kg ha\(^{-1}\)).

Khan et al. (2002) reported that the grain yield of green gram increased with seed inoculation with *Rhizobium* than uninoculated green gram.

Kumar et al. (2003) reported that seed inoculation with *Rhizobium* significantly increase the grain yield of green gram over no inoculation.

On sandy loam soil at Hisar, Satish et al. (2003) observed that the seed inoculation with *Rhizobium* significantly increased the grain yield of green gram cv. Asha over no inoculation. Similar beneficial effect of *Rhizobium* inoculation on yield and yield attributes of green gram has been reported earlier by Sarkar et al. (1993) and Singh et al. (1993).

Sharma et al. (2006) reported that inoculation of the plant with *Rhizobium* resulted in higher grain yield.

Yadav et al. (2011) an experiment was conducted during summer season of 2009 at Sultnapur, district Kannauj (U.P.) to study the impact of biofertilizers on the growth and yield of green gram. Two levels of chemical fertilizers (60 & 80 Kg N ha\(^{-1}\)) with the combination of different biofertilizers (PSB, Azotobacter, Azospirillum) were used. The difference in the growth parameters such as plant height, length to branch, no. of pods, pod length and grain yield was studied at the interval of 35 and 70 days. Plant treated with PSB + 80 Kg N ha\(^{-1}\) produced the highest yield.
Husssain et al. (2011) from Kashmir observed that Rhizobium + PSB inoculation produced maximum grain yield (8.82 q ha\(^{-1}\)) which was slightly higher than obtained with either Rhizobium or PSB separately at 8.18 and 8.80 q ha\(^{-1}\), respectively.

**2.4.10 On straw yield**

Khan et al. (2002) reported that the straw yield in green gram increased with Rhizobium inoculation than uninoculated green gram.

Yadav et al. (2010) conducted an experiment in 2007-08 and reported that seed inoculation of green gram with Rhizobium a significant increase in straw yield 29.89 and 42.3 q ha\(^{-1}\), respectively as compared to control and other treatment.

**2.4.11 On nutrient contents and their uptake**

Singh and Kumari (1990) conduct an investigation at Varanasi and found that seed inoculation with Rhizobium increased P content in straw and grain and N content in straw only.

Barar and Sidhu (1992) observed increase in N, P and Mo content in straw and grain and crude protein content in grain of green gram due to Rhizobium inoculation. Similarly, Singh et al. (1994) also recorded higher N and P content in grain by Rhizobium inoculation.

Deka and Kaketi (1996) found that seed inoculation of green gram with Rhizobium significantly increased the N content and uptake over lower level and control.

Khan et al. (2002) reported that the phosphorus content and uptake in green gram increase with Rhizobium inoculation.
Mishra (2003) reported that *Rhizobium* inoculation of the grain had the highest N content and uptake and protein yield in grain and straw in green gram.

Bhat *et al.*, (2010) reported that inoculation with *Rhizobium* significantly increased total nitrogen (89.15 Kg ha\(^{-1}\)), phosphorus (9.17 Kg ha\(^{-1}\)) and potassium (55.8 Kg ha\(^{-1}\)) uptake by green gram.
MATERIALS AND METHODS

The present investigation entitled “Effect of varieties and fertility levels on growth and yield of green gram (Vigna radiata L.) in custard apple (Annona squamosa L.) based agri-horti system under rainfed condition” was carried out during Kharif season of 2011-12. The edaphic and climatic condition under which the experimental crop was raised and materials and techniques employed in conducting the experiment are being described in this chapter.

3.1 Experimental site

The experiment was carried out at the Agricultural Research Farm, Rajiv Gandhi South Campus, Banaras Hindu University, Barkachha which is situated in Vindhyaan region of district Mirzapur (U. P.) (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 are raised. Vindhyaan soils are invariably poor in soil fertility status. This region comes under agro-climatic zone III A (semi-arid eastern plain zone) and the region is mostly rainfed.

3.2 Climate and weather

The climate of Barkachha is typically semi-arid, characterized by extremes of temperature both in summer and winter with low rainfall and moderate humidity. The average maximum temperature in summer is as high as 39.65°C and average minimum temperature in winter falls below 8.12°C.
The rainfall during the cropping period was recorded from the meteorological observatory of the Krishi Vigyan Kendra, B.H.U., Barkachha, Mirzapur. The total rainfall during the crop season was 1080 mm. The maximum and minimum temperature is 34.7°C and 16°C. The metrological data of Mirzapur district is given in Table 3.1 and shown in Fig 3.1.

3.3 Soil characteristics of experimental field

The soil of the experimental field was sandy loam in texture with low drainage. It was acidic in reaction, poor in nitrogen as well as phosphorus and moderate in potash. Composite soil samples prior to commencement of the experiment were collected to determine mechanical composition and physico-chemical properties of the soil and the data are presented in Table 3.2.
Table 3.1: Mean week-wise meteorological data during crop season *kharif*, 2011.

<table>
<thead>
<tr>
<th>Standard Weeks (SW)</th>
<th>Month</th>
<th>Date</th>
<th>Rainfall (mm)</th>
<th>Temperature (°C)</th>
<th>Max.</th>
<th>Min.</th>
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<td>July</td>
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<tr>
<td>35</td>
<td></td>
<td>27-02</td>
<td>61.1</td>
<td>32.5</td>
<td>27.4</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td></td>
<td>03-09</td>
<td>44</td>
<td>32</td>
<td>26.2</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>September</td>
<td>10-16</td>
<td>28.6</td>
<td>30.5</td>
<td>26.3</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td></td>
<td>17-23</td>
<td>68.8</td>
<td>30.7</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td></td>
<td>24-30</td>
<td>296.4</td>
<td>30</td>
<td>24.3</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
<td>01-07</td>
<td>25.2</td>
<td>31.1</td>
<td>23.8</td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>October</td>
<td>08-14</td>
<td>3.8</td>
<td>33.1</td>
<td>23.5</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td></td>
<td>15-21</td>
<td>3.6</td>
<td>31.7</td>
<td>20.4</td>
<td></td>
</tr>
<tr>
<td>43</td>
<td></td>
<td>22-28</td>
<td>4.3</td>
<td>31.6</td>
<td>19.9</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td></td>
<td>29-04</td>
<td>0</td>
<td>30.8</td>
<td>16</td>
<td></td>
</tr>
</tbody>
</table>

Observatory:– KVK, B.H.U., Barkachha, Mirzapur.
Table 3.2: Mechanical and physico-chemical analyses of soil of the experimental field.

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Value</th>
<th>Rating</th>
<th>Method</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Mechanical analyses</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand (%)</td>
<td>56.24</td>
<td></td>
<td>Hydrometer</td>
<td>Bouyoucos (1962)</td>
</tr>
<tr>
<td>Silt (%)</td>
<td>29.18</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clay (%)</td>
<td>14.58</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Textural class</td>
<td>Sandy loam</td>
<td></td>
<td>Textural triangle</td>
<td>Black et al. (1965)</td>
</tr>
<tr>
<td><strong>2. Physical constants</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulk density (mg/m³)</td>
<td>1.45</td>
<td></td>
<td>Core sample</td>
<td>Black et al. (1965)</td>
</tr>
<tr>
<td>Particle density (mg/m³)</td>
<td>2.65</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>3. Chemical analyses</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic carbon (%)</td>
<td>0.27</td>
<td>Low</td>
<td>Wet digestion method</td>
<td>Walkley and Black (1934)</td>
</tr>
<tr>
<td>Available N (Kg ha⁻¹)</td>
<td>183.67</td>
<td>Low</td>
<td>Alkaline potassium permanganate</td>
<td>Subbiah &amp; Asija (1956)</td>
</tr>
<tr>
<td>Available P₂O₅ (Kg ha⁻¹)</td>
<td>10.55</td>
<td>Medium</td>
<td>0.5 M NaHCO₃ extractable</td>
<td>Olsen et al. (1954)</td>
</tr>
<tr>
<td>Available K₂O (Kg ha⁻¹)</td>
<td>125.8</td>
<td>Medium</td>
<td>1N neutral ammonium acetate</td>
<td>Piper, (1966)</td>
</tr>
<tr>
<td>pH (1:2.5 soil: water suspension)</td>
<td>5.6</td>
<td>Slightly acidic</td>
<td>Glass electrode digital pH meter</td>
<td>Sparks, (1996)</td>
</tr>
<tr>
<td>EC (1:2.0 soil: water suspension)</td>
<td>0.30</td>
<td>Normal</td>
<td>Systronics electrical conductivity meter</td>
<td>Sparks, (1996)</td>
</tr>
</tbody>
</table>
3.4 Cropping history of experimental field

The crop sequences followed in the experimental field during the past five years have been presented in Table 3.3. The cropping history of the experimental site clearly indicates that the field was not cropped continuously and kept fallow during one consecutive Kharif and Rabi seasons (2007-08) followed by fallow in Rabi during 2009-10 to 2010-11. During 2008-09 green gram-mustard sequence was taken, in 2009-10 green gram and in 2010-11 pearl millet was taken in Kharif season thus, the fertility set up has not been disturbed. Hence, as such the field is ideally suitable for the experiment.

Table 3.3: Cropping history of experimental field

<table>
<thead>
<tr>
<th>Year</th>
<th>Season</th>
<th>Rainy (Kharif)</th>
<th>Winter (Rabi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-08</td>
<td>Fallow</td>
<td>Fallow</td>
<td></td>
</tr>
<tr>
<td>2008-09</td>
<td>Green gram</td>
<td>Mustard</td>
<td></td>
</tr>
<tr>
<td>2009-10</td>
<td>Green gram</td>
<td>Fallow</td>
<td></td>
</tr>
<tr>
<td>2010-11</td>
<td>Pearl millet</td>
<td>Fallow</td>
<td></td>
</tr>
<tr>
<td>2011-12</td>
<td>Experimental crop</td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>

3.5 Experimental details

The field experiment was laid out during Kharif season of 2011 in six years old custard apple which was planted in August 2006 at a spacing of 5m x 5m meter. Green gram was sown as an intercrop. The experiment was conducted in factorial randomized block design having four levels of N, P2O5 and FYM and seed inoculated by strain *Rhizobium* MOR-1 and Phosphate Solubilizing Bacteria (PSB, *Bacillus subtilis*) of green gram (*Vigna radiata* L.) with three replication. The inoculants were obtained from the Department of Plant Pathology, Institute of Agricultural
Materials and Methods

Sciences, Banaras Hindu University. The treatments were randomized as per statistical procedure.

**Table 3.4: The layout plan of experimental field is as follows**

<table>
<thead>
<tr>
<th>Experimental design</th>
<th>Factorial randomized block design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of treatment</td>
<td>8</td>
</tr>
<tr>
<td>Number of replication</td>
<td>3</td>
</tr>
<tr>
<td>Total number of plots</td>
<td>24</td>
</tr>
<tr>
<td>Gross plot size</td>
<td>3 m x 3.5 m</td>
</tr>
<tr>
<td>Net plot size</td>
<td>1.80 m x 2.5 m</td>
</tr>
<tr>
<td>Plot border</td>
<td>50 cm</td>
</tr>
<tr>
<td>Row to row distance</td>
<td>30 cm</td>
</tr>
<tr>
<td>Plant to plant distance</td>
<td>10 cm</td>
</tr>
</tbody>
</table>

**3.5.1 Varieties**

V<sub>1</sub> - HUM-12

V<sub>2</sub> - HUM-16

**3.5.2 Fertility levels**

F<sub>1</sub> - 100% RDF (20 Kg N and 40 Kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>)

F<sub>2</sub> - 75% RDF + *Rhizobium* + PSB + 25% N through FYM

F<sub>3</sub> - 50% RDF + *Rhizobium* + PSB + 50% N through FYM

F<sub>4</sub> – No application

**3.5.3 Treatment Combination**

V<sub>1</sub>F<sub>1</sub>, V<sub>1</sub>F<sub>2</sub>, V<sub>1</sub>F<sub>3</sub>, V<sub>1</sub>F<sub>4</sub>, V<sub>2</sub>F<sub>1</sub>, V<sub>2</sub>F<sub>2</sub>, V<sub>2</sub>F<sub>3</sub>, V<sub>2</sub>F<sub>4</sub>
Table 3.5: Treatment details

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>HUM-12 + 100% RDF</td>
</tr>
<tr>
<td>2.</td>
<td>HUM-12 + 75% RDF + Rhizobium + PSB +25% N through FYM</td>
</tr>
<tr>
<td>3.</td>
<td>HUM-12 + 50% RDF + Rhizobium + PSB+50% N through FYM</td>
</tr>
<tr>
<td>4.</td>
<td>HUM-12 + No application</td>
</tr>
<tr>
<td>5.</td>
<td>HUM-16 + 100% RDF</td>
</tr>
<tr>
<td>6.</td>
<td>HUM-16 + 75% RDF + Rhizobium + PSB +25% N through FYM</td>
</tr>
<tr>
<td>7.</td>
<td>HUM-16 + 50% RDF + Rhizobium + PSB+50% N through FYM</td>
</tr>
<tr>
<td>8.</td>
<td>HUM-16 + No application</td>
</tr>
</tbody>
</table>

3.6 Experimental crops and variety

Green gram (*Vigna radiate* L.) chosen for conducting the experiment in custard apple based agri-horti system for their comparison with sole crop.

3.6.1 Variety

**HUM-12**- Green gram variety, developed from Banaras Hindu University, Varanasi. A recommended variety for cultivation in summer and *Kharif* season, matures in 65-70 days. 1000 grains weight is 30-33 g. The grain is green and medium large. Yield potential is 10-12 q ha⁻¹.

**HUM16**- Green gram variety, developed from Banaras Hindu University, Varanasi, has been identified for North East Plains Zone (NEPZ). It is suitable for summer cultivation and has yield superiority of 1520 kg/ha. It is the first genotype in NEPZ which matures in 60-63 days and suitable for summer
cultivation after harvesting of wheat. It is quite bold seeded having market preference and has shown resistance to MYMV, the most prevalent disease of the Zone.

3.7 Agronomic practices

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

Table 3.6: Schedule of field operations

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Operation</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A).</td>
<td>Pre-sowing operations</td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Land preparation</td>
<td></td>
</tr>
<tr>
<td>(i)</td>
<td>First plough</td>
<td>29.07.2011</td>
</tr>
<tr>
<td>(ii)</td>
<td>Second plough</td>
<td>31.07.2011</td>
</tr>
<tr>
<td>2.</td>
<td>Layout and experiment</td>
<td>02.08.2011</td>
</tr>
<tr>
<td>(B).</td>
<td>Sowing operations</td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Fertilizer application and sowing</td>
<td>03.08.2011</td>
</tr>
<tr>
<td>(C).</td>
<td>Post-sowing operations</td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Thinning</td>
<td>18.08.2011</td>
</tr>
<tr>
<td>2.</td>
<td>Weeding and hoeing</td>
<td>21.08.2011</td>
</tr>
<tr>
<td>3.</td>
<td>Harvesting</td>
<td></td>
</tr>
<tr>
<td>(i)</td>
<td>First picking</td>
<td>05.10.2011</td>
</tr>
<tr>
<td>(ii)</td>
<td>Second picking</td>
<td>08.10.2011</td>
</tr>
<tr>
<td>4.</td>
<td>Threshing</td>
<td>11.10.2011</td>
</tr>
</tbody>
</table>

3.7.1 Land preparation

The field was ploughed with the help of mould board plough after reaching the appropriate moisture level followed by harrowing and planking. Thereafter, the experiment was laid out as per plan and design.

3.7.2 Fertilizer and manure application

Fertilizers and manures were applied as per treatment combination. The sources of N, P₂O₅ and K₂O were Urea, DAP,
FYM. Seed was treated with *rhizobium* and PSB as per treatment.

### 3.7.3 Seed inoculation

In two 500 ml beakers, water was boiled and to each beaker 60 g molasses were added and dissolved and then cooled. To one beaker *rhizobium* inoculant was mixed and to another beaker phosphate solubilizing bacteria inoculant was mixed to obtain their slurries. One half of the seed of both varieties was heaped. One half of seed of both varieties was inoculated with both *rhizobium* and phosphate solubilizing bacteria. The inoculated seed after uniformly inoculation was spread and dried under shade and was sown immediately after drying.

### 3.7.4 Seed rate and sowing

The seed were sown manually in the furrow opened by *kudal* at a row distance of 30 cm as per treatment. Relatively higher seed rate (20 kg ha⁻¹) was used for optimum maintenance of plant population. A plant spacing of 10 cm within the row was maintained by thinning, 15 days after sowing.

### 3.7.5 Thinning and intercultural operation

Extra plants were thinned to maintain the desired plant population at 15 days after sowing. One weeding was done manually by *khurpi* at 18 days after sowing to control weeds.

### 3.7.6 Harvesting and threshing

Crop was harvested at complete maturity as judged by visual observation. The border rows were harvested first and kept aside. Thereafter, the net plots were harvested by hand picking of the pods when nearly 80 per cent pods were matured and harvested crop plant was left in the field for drying for a period of 3-4 days. Thereafter, small bundles were made and
taken to the threshing floor. Bundle weight (straw) was recorded before threshing.

### 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 an interval of 20 days i.e. 20\textsuperscript{th}, 40\textsuperscript{th}, 60\textsuperscript{th} days after sowing and at maturity.

Yield attributes and yield were studied before and after harvesting as per investigation required.

#### 3.8.1 Growth attributes

##### 3.8.1.1 Plant height (cm)

Height of randomly selected and marked plants from each plot was measured from base of the plants up to growing tip of main stem. The average plant height was calculated by taking the mean of observation of five plants and expressed in cm.

##### 3.8.1.2 Root nodules plant\textsuperscript{-1}

Five plants were randomly uprooted along with soil from the penultimate rows from each plot. Nodules excised from the roots with a scalpel were counted, and expressed as number plant\textsuperscript{-1}.

##### 3.8.1.3 Trifoliate leaves plant\textsuperscript{-1}

The number of trifoliate leaves plant\textsuperscript{-1} of green gram was counted at different stages of the crop growth from the selected tagged plants per plot and mean of observation of five plants was computed.
3.8.1.4 Branches plant$^{-1}$

Branches having at least two fully developed trifoliate leaves were considered for recording of number of branch.

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

For recording dry matter accumulation, 5 plants from border row each plot were cut from the ground level. Sampled plants were sun dried first then dried in an oven for 24 hours to get constant dry weight. Thereafter, the average dry weight was recorded in g plant$^{-1}$.

3.8.2 Yield attributing characters

The following observations on yield attributes and yield studies were recorded during the experimentation:

3.8.2.1 Number of pod plant$^{-1}$

Total number of pod on the tagged plants was counted and average number of pod plant$^{-1}$ was recorded.

3.8.2.2 Pod length (cm)

Length of ten randomly selected pods was measured from five tagged plants and average was worked out to get the pod length.

3.8.2.3 Number of grains pod$^{-1}$

The ten randomly selected pods from each five tagged plants per plot were taken out and total number of grains was counted. Average number of grains pod$^{-1}$ was then calculated and recorded.

3.8.2.4 Test weight (g)

Randomly selected 1000 grains from the grain yield samples of crop were counted from each plot and their combined weight was recorded to get the test weight.
3.8.2.5 Grain and straw yield (kg ha\(^{-1}\))

The plants from the net plot area were harvested, bundled and weighed after sun drying. Thereafter, the material was transferred to threshing floor, threshed, cleaned and grain yield (kg plot\(^{-1}\)) was recorded. The difference of the bundle weight and the grain yield gave the straw yield of crop. Yield obtained in kg plot\(^{-1}\) were converted to yield in kg ha\(^{-1}\) by multiplying with appropriate conversion factor.

3.8.2.6 Harvest index

The harvest index was calculated by dividing the economic yield by the biological yield and multiplying by 100.

\[
\text{Harvest index} = \frac{\text{Economic yield (kg ha}^{-1})}{\text{Biological yield (kg ha}^{-1})} \times 100
\]

3.9 Plant analysis

The plants were harvested at maturity, washed sequentially with 0.2% detergent solution, 0.1 N HCl and finally with double distilled water. The plant material was dried at 60\(^{\circ}\)C for 48 h in a hot air oven. Dry plant tissue was finely grounded.

3.9.1 Estimation of nitrogen in plant and grain sample

Nitrogen content in plant and grain sample was determined by Modified Kjeldahl Method as per procedure. In a digestion tube 0.5 g of powdered plant straw was taken and 10 ml of diacid solution (9:1, H\(_2\)SO\(_4\):HClO\(_4\)) was added and kept for overnight then 10g of sulphate mixture [(20 parts K\(_2\)SO\(_4\) + 1 part catalyst mixture (20 parts CuSO\(_4\) + 1 part selenium powder)] was added and heating was done in a digestion chamber till a clear colourless solution appears, then cooled and
filtered through Whatman No. 42 filter paper in a 50 mL volumetric flask and made up to the volume with distilled water.

Ten mL of 4% boric acid solution containing bromocresol green and methyl red indicator was taken in a conical flask, outlet of distillation apparatus was dipped into boric acid solution. Five mL of the aliquot was taken and transferred to the distillation tube of Kjeltec Semi-Auto Nitrogen Analyzer and 10 mL of 40 % NaOH was sucked and added to the distillation tube. Then the instrument was put on distillation for 9 min. After completion of distillation, the boric acid was titrated against 0.02 N H₂SO₄. Blank was also run and N content was calculated by formula.

**Calculation**

\[
\text{Percent N in Plant material} = \frac{0.02 \times T \times 0.014 \times 50}{5 \times 0.5} 
\]

\[T = \text{Sample reading} - \text{Blank reading}\]

**3.9.2 Digestion for P, K, in green gram straw and grain**

One gram dried and powdered plant sample (20 mesh) was taken in a 50 mL digestion tube and 10 mL di-acid mixture (4:1 v/v HNO₃: HClO₄) was added to it and was kept overnight. It was then digested on a block digester till a colourless solution was obtained. The volume of acid was reduced till the flask contained only moist residue. The flask was cooled and 25 mL of distilled water was added. The solution was filtered into a 50 mL volumetric flask and diluted up to mark.
3.9.2.1 Colour development of Phosphorus

Two mL of digest was taken in a 25 mL volumetric flask and 2 drops of 2, 4 di-nitrophenol indicator was added. Ammonium solution was added till yellow colour appeared and then 6 N HCl was added (dropwise) till it become colourless. Then 5 mL of Vanadate molybdate solution was added and diluted to 25 mL with distilled water, mixed well and the intensity of yellow colour was read on spectrophotometer by using blue filter at 440 nm wave length. A blank was also run without P solution simultaneously. First standard reading and then sample reading was taken. Phosphorus content in straw and grain was calculated using standard curve and expressed as total P (%). Same procedure was followed to determination of P content in grain except weight of sample in case of grain only 0.2 g powdered was taken (Jackson, 1967).

Calculation

$$\text{Total P \%} = \frac{\text{Abs.} \times \text{dilution factor}}{\text{Slope of std curve} \times 10000}$$

3.9.2.2 For Potassium content in straw and grain

Potassium content of plant and grain was determined by Flame Photometer method (Jackson, 1973). In case of potassium, digested extract was used directly for flame photometer determination of potassium. Potassium content of digested straw and grain was determined by Flame Photometer. K content was calculated using the standard curve and expressed as total K.
**Calculation**

\[
\text{Total K} \% = \frac{R \times \text{dilution factor}}{10000}
\]

R = Flame photometer reading

3.10 **Growth parameters of custard apple**

The following growth parameters of custard apple, situated at border of the plot, were recorded at the scheduled dates.

3.10.1 **Height**

The height of custard apple was measured from base of the plants up to growing tip of main stem. The plant height was measured and expressed in meter.

3.10.2 **Canopy**

The canopy area of custard apple was recorded with the help of meter tape and it was recorded from the highest canopy diameter in meter.

3.10.3 **Stem girth**

The stem girth of custard apple was recorded from base of the plants in cm which was situated at the plot of the crops.

3.10.4 **Shading**

The shading area of the custard apple was recorded with the help of meter tape and measured as width and length in meter.

3.11 **Economics**

The cost of cultivation was worked out by taking into consideration all the expenses incurred. Gross income was worked out by multiplying grain and straw yields of the crop with their prevailing market prices. Calculations were made as per normal rates prevalent at the Research Farm, R.G.S.C.
(B.H.U.), Barkachha, Mirzapur. The cost of fertilizers, manure, and seed etc. were taken as per prevailing market prices. Net return (Rs ha\(^{-1}\)) and benefit:cost ratio were calculated with the help of the following formula:

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

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

**3.12 Statistical analysis**

For determining the significance between the treatment means and to draw valid conclusion, statistical analysis was made. Data obtained from various observations were subjected to statistical analysis by adopting appropriate method of “Analysis of Variance”. The significance of the treatment effect was judged with the help of ‘F’ test (Variance ratio). The difference of the treatments mean was tested using critical difference (C. D.) at 0.05% level of probability (Gomez and Gomez, 1976).

If the variance ratio (F test) was found significant at 0.05% level of significance, the standard error of mean (S.Em.\(\pm\)) and critical differences (CD) were calculated for further treatment comparisons.

\[
\text{S.Em.\(\pm\)} = \sqrt{\frac{V_e(a)}{r \times C}}
\]

\[
\text{C.D. at 0.05%} = \text{S.Em.\(\pm\)} \times \sqrt{2} \times t \text{ value at } 5\% \text{ of error (a) d.f.}
\]
Fig. 3.2: Experimental layout
EXPERIMENTAL FINDINGS

The present investigation entitled “Effect of varieties and fertility levels on growth and yield of greengram (*Vigna radiata* L.) in custard apple (*Annona squamosa* L.) based agri-horti system under rainfed condition” was conducted during *kharif* season of 2011 at the Agricultural Research Farm, Rajiv Gandhi South Campus, Banaras Hindu University, Barkachha, Mirzapur (U.P.). The observation recorded during the course of present investigation pertaining to growth, yield attributes, and yield, nutrient content and uptake and relative economics are presented in different tables and described in this chapter after statistical analysis of observed data during the conduct of experiment.

4.1 Growth attributes

4.1.1 Plant height (cm)

The data on plant height as affected by varieties and fertility levels, recorded at 20, 40, 60 days after sowing (DAS) and at harvest are presented in Table 4.1.

Variation in plant height was significantly influenced by both the varieties of green gram at all the growth stages of crop except 20 DAS. The variety HUM-16 (18.03, 29.45, 34.54 and 35.26 cm) had taller plant than HUM-12 at 20, 40, 60 DAS and at maturity stage of green gram, respectively.

Throughout the crop season, the tallest (21.31, 33.60, 38.98 and 39.55 cm) and smallest (10.62, 21.81, 29.07 and 29.92 cm) plant was recorded in fertility level *F*₂ (75% RDF +
Rhizobium + PSB + 25% N through FYM) and F₄ (No application), respectively. Among fertility levels, the F₂ recorded significantly taller plant over rest of the fertility treatments at all the growth stages. The plant height increases was 100.65, 54.05, 34.09 and 32.19 per cent in F₂ as compared to F₄ at 20, 40, 60 DAS and maturity stage, respectively. The fertility level F₃ (50% RDF + Rhizobium + PSB + 50% N through FYM) was statistically at par with F₁ (100% RDF) at 40 and 60 DAS. Interaction effect between varieties and fertility levels were non-significant.

4.1.2 Number of trifoliate leaves plant⁻¹

It is evident from the data presented in Table 4.2 the trifoliate leaves plant⁻¹ increased with the advancement of crop growth up to 60 DAS and decreased thereafter at harvest.

Variations in number of trifoliate leaves due to varieties were significant. The variety HUM-16 recorded the higher (4.31, 6.76, 13.73 and 11.83) number of trifoliate leaves than HUM-12 throughout the crop growth period.

Data related to number of trifoliate leaves revealed that fertility levels significantly influenced the number of trifoliate leaves of green gram. Fertility level F₂ (75% RDF + Rhizobium + PSB + 25% N through FYM) recorded the more (5.04, 8.68, 15.13 and 13.20) and F₄ (No application) had the less (3.29, 5.11, 11.77 and 9.39) number of trifoliate leaves at 20, 40, 60 DAS and maturity stage, respectively. At maturity stage F₁ (100% RDF) and F₃ (50% RDF + Rhizobium + PSB + 50% N through FYM) had statistically similar number of trifoliate leaves. However, the fertility level F₃ was statistically at par with F₁ at 20 and 60 DAS. Interaction effect between varieties and fertility levels had no significant effects on number of trifoliate leaves.
4.1.3 Number of branches plant⁻¹

The data on number branches plant⁻¹ as influenced by varieties and fertility levels are presented in Table 4.3.

Both the varieties showed significant differences in number of branches plant⁻¹ of green gram at all the growth stages. The number of branches plant⁻¹ recorded by the variety HUM-16 (4.23, 4.80 and 5.05) at 40, 60 DAS and at maturity stage were higher than HUM-12 (3.90, 4.50 and 4.70), respectively.

Throughout the crop season, the fertility level F₂ (75% RDF + Rhizobium + PSB + 25% N through FYM) and F₄ (No application) recorded the maximum (4.90, 5.70 and 6.07) and the minimum (3.30, 3.80 and 3.93) number of branches plant⁻¹. Among fertility levels F₂ had significantly higher number of branches plant⁻¹ over rest of the fertility treatments at all the growth stages. However, the fertility level F₃ (50% RDF + Rhizobium + PSB + 50% N through FYM) was statistically at par with F₁ (100% RDF) at 40 and 60 DAS and maturity stage. Interaction effect between varieties and fertility levels were non-significant.

4.1.4 Number of nodules plant⁻¹

The data pertaining to effect of varieties and fertility levels on number of nodules plant⁻¹ has been presented in Table 4.3.

Variation in number of nodules plant⁻¹ was significantly influenced by both the varieties of green gram. The variety HUM-16 (11.20 and 22.41) recorded significantly higher number of nodules plant⁻¹ than HUM-12 (10.43 and 21.38) at 20 and 40 DAS, respectively.

Scanning of data in the Table 4.3 revealed that the fertility level F₂ (75% RDF + Rhizobium + PSB + 25% N through FYM)
and F₄ (No application) recorded the maximum (14.18 and 26.20) and the minimum (7.47 and 17.24) number of nodules at 20 and 40 DAS, respectively. Among fertility levels the F₂ had significantly higher number of nodules plant⁻¹ over rest of the fertility treatments at 20 and 40 DAS. Interaction effect was non-significant between variety and fertility levels.

4.1.5 **Dry matter accumulation (g plant⁻¹)**

Critical analyses of the data presented in Table 4.4 clearly indicate that significant variations in observed dry matter accumulation due to varieties and fertility treatments.

The variety HUM-16 (2.25, 7.53, 11.96 and 12.16 g) had significantly higher dry matter accumulation as compared to HUM-12 (2.01, 7.06, 11.39 and 11.57 g) at 20, 40, 60 DAS and maturity stages, respectively. In case of fertility levels, the maximum (2.64, 8.93, 14.05 and 14.35 g) and the minimum (1.47, 5.68, 8.70 and 8.84 g) dry matter accumulation was observed in F₂ (75% RDF + Rhizobium + PSB + 25% N through FYM) and F₄ (No application), respectively. The fertility level F₃ (50% RDF + Rhizobium + PSB + 50% N through FYM) had statistically similar dry matter accumulation as compared to F₁ (100% RDF) at all the growth stages. Interaction effect between varieties and fertility levels were non-significant.

4.2 **Yield attributes**

The data pertaining to yield attributes viz. number of pods plant⁻¹, number of grains pod⁻¹, pod length (cm) and 1000-grain weight (g) as influenced by varieties and fertility levels recorded at harvest stage and data are presented in Table 4.5 and depicted graphically in Fig 4.1.
4.2.1 Number of pods plant\(^{-1}\)

Variations in number of pods plant\(^{-1}\) did not differ significantly due to varieties. The variety HUM-16 (9.96) was recorded higher number of pods compared to HUM-12 (9.93).

The data in Table 4.5 reveals that the fertility levels significantly influenced the number of pods plant\(^{-1}\) of green gram. The fertility level F\(_2\) (75% RDF + Rhizobium + PSB + 25% N through FYM) recoded significantly more (10.90) number of pods plant\(^{-1}\). However, all the fertility treatments had significantly more number of pods plant\(^{-1}\) as compared to F\(_4\) (8.60) whereas, the fertility level F\(_3\) (50% RDF + Rhizobium + PSB + 50% N through FYM) had statistically similar number of pods plant\(^{-1}\) in comparison to F\(_1\) (100% RDF). Interaction effect between varieties and fertility levels were non-significant.

4.2.2 Pod length (cm)

The varieties had significant effect on variations in pod length of green gram. The longer (8.07 cm) pod was recorded in variety HUM-16 than HUM-12 (7.63 cm). Further analyses of data in the Table 4.5 clearly revealed that variations in pod length due to fertility levels were also significant. The maximum (8.51 cm) and the minimum (7.45 cm) pod length was recorded by F\(_2\) (75% RDF + Rhizobium + PSB + 25% N through FYM) and F\(_4\) (No application), respectively. Among fertility levels, F\(_2\) recorded significantly higher pod length over rest of the fertility treatments whereas, F\(_3\) and F\(_1\) were statistically at par to each other. Interaction effect between varieties and fertility levels were non-significant.
4.2.3 Number of grains pod$^{-1}$

The number of grains pod$^{-1}$ was more in variety HUM-16 (9.64) as compared to HUM-12 (9.44). However, the differences among the varieties were non-significant. The number of grains pod$^{-1}$ was significantly influenced by fertility levels. The maximum mean (10.07) number of grains pod$^{-1}$ was recorded in fertility level F$_2$ (75% RDF + Rhizobium + PSB + 25% N through FYM) and F$_4$ (No application) recorded the minimum mean (8.53) number of grains pod$^{-1}$ of green gram. The fertility level F$_2$ was statistically at par with F$_3$ (50% RDF + Rhizobium + PSB + 50% N through FYM). Interaction effect between varieties and fertility levels were non-significant.

4.2.4 1000-grain weight (g)

The data related to 1000-grain weight showed that the variety HUM-16 (25.93 g) had higher test weight as compared to HUM-12 (25.73 g). However, the differences were non-significant.

The data in the Table 4.5 clearly indicate that the fertility level F$_2$ (75% RDF + Rhizobium + PSB + 25% N through FYM) and F$_4$ had the maximum mean (27.16 g) and the minimum mean (23.82 g) of test weight, respectively. The fertility treatment F$_3$ (50% RDF + Rhizobium + PSB + 50% N through FYM) and F$_1$ (100% RDF) were at par with each other. Interaction effect was non-significant between variety and fertility levels.

4.3 Grain yield, straw yield (Kg ha$^{-1}$) and harvest index (%)

The data on grain yield, straw yield (Kg ha$^{-1}$) and harvest index (%) as influenced by varieties and fertility levels have been presented in Table 4.6 and depicted graphically in Fig 4.2.
4.3.1 Grain yield (Kg ha\(^{-1}\))

Variations in grain yield due to varieties were non-significant. The variety HUM-16 recorded higher (829.35 Kg ha\(^{-1}\)) grain yield as compared to HUM-12 (805.93 Kg ha\(^{-1}\)).

Statistical analysis of data in Table 4.6 revealed that the fertility levels significantly influenced the green gram grain yield. The fertility treatment F\(_2\) (75% RDF + Rhizobium + PSB + 25% N through FYM) recorded significantly highest (978.71 Kg ha\(^{-1}\)) grain yield followed by F\(_3\) (892.74 Kg ha\(^{-1}\)) and F\(_1\) (822.09 Kg ha\(^{-1}\)), whereas significantly less (577.02 Kg ha\(^{-1}\)) grain yield recorded in F\(_4\) (No application). The fertility level F\(_3\) (50% RDF + Rhizobium + PSB + 50% N through FYM) was statistically at par with F\(_1\) (100% RDF). Interaction effect was non-significant between variety and fertility levels.

4.3.2 Straw yield (Kg ha\(^{-1}\))

Analysis of data clearly showed that the varieties significantly influenced the differences in the straw yield of green gram. The variety HUM-16 had statistically higher (2641.04 Kg ha\(^{-1}\)) straw yield as compared to HUM-12 (2536.55 Kg ha\(^{-1}\)).

Perusal of data in Table 4.6 revealed that the fertility levels significantly influenced the straw yield. The maximum (2965.24 Kg ha\(^{-1}\)) and the minimum (1940.38 Kg ha\(^{-1}\)) straw yields were recorded in F\(_2\) (75% RDF + Rhizobium + PSB + 25% N through FYM) and F\(_4\) (No application), respectively. The fertility level F\(_2\) was statistically at par with F\(_3\) (50% RDF + Rhizobium + PSB + 50% N through FYM). Interaction effect was non-significant between variety and fertility levels.
4.3.3 Harvest index (%)

Variations in harvest index due to varieties were non-significant. The variety HUM-16 had statistically higher (24%) harvest index as compared to HUM-12 (23.79%).

The data in Table 4.6 revealed that the fertility levels were significantly influenced the harvest index. The fertility level F₂ (75% RDF + Rhizobium + PSB + 25% N through FYM) was recorded higher (24.83%) harvest index followed by F₃ (23.85%) and F₁ (23.71%) whereas, significantly less harvest index recorded in F₄ (23.19%). The fertility level F₃ (50% RDF + Rhizobium + PSB + 50% N through FYM), F₁ (100% RDF) and F₄ (No application) were statistically at par with each other. Interaction effect was non-significant between variety and fertility levels.

4.4 Yield of custard apple (Kg ha⁻¹)

The custard apple has the advantage of cropping in late winter and spring when the preferred members of the genus are not in season. It is picked when it has lost all green color and ripens without splitting so that it is readily sold in local markets. If picked green, it will not color well and will be of inferior quality. The tree is naturally a fairly heavy bearer. The average yield was noticed 32.5 fruits plant⁻¹ with an average 80g fruit⁻¹ weight. Average yield was recorded 2.60 Kg tree⁻¹ (1040 Kg ha⁻¹) in the Rajiv Gandhi South Campus, Banaras Hindu University, Barkachha, (Mirzapur), Uttar Pradesh.

4.5 Nutrient (N, P and K) content (%)

Analysis of N, P and K contents in grain and straw samples as influenced due to varieties and fertility levels are presented in Table 4.7.
4.5.1 Nutrient (N, P and K) content (%) in grain

Perusal of data clearly indicated the varieties had non-significant differences in N, P and K content in grain. The variety HUM-16 (3.65, 3.50 and 1.08%) was recorded higher N, P and K content as compared to HUM-12 (3.60, 3.41 and 1.06%), respectively.

Among fertility levels, F2 (75% RDF + Rhizobium + PSB + 25% N through FYM) was recorded significantly higher (3.76, 3.74 and 1.09) N, P and K content in grain, thus all the fertility levels were statistically at par with respect to N, P and K content. The fertility level F4 recorded the minimum (3.46, 3.16 and 1.01%) value of N, P and K content in grain. Interaction between varieties and fertility levels had non significant effect on N, P and K content in grain.

4.5.2 Nutrient (N, P and K) content (%) in straw

Statistical analysis of data showed that N, P and K content in straw did not differ significantly due to varieties.

Observation recorded revealed that the fertility level F2 (75% RDF + Rhizobium + PSB + 25% N through FYM) and F4 (No application) were recorded the maximum (1.74, 0.21 and 2.70%) and the minimum (1.45, 0.15 and 2.14%) N, P and K content in straw, respectively. In case of K content the fertility level F2 was statistically at par with F3 (50% RDF + Rhizobium + PSB + 50% N through FYM). Interaction between varieties and fertility levels had non significant effect on N, P and K content in straw.

4.6 Nutrient (N, P and K) uptake (Kg ha⁻¹)

The data pertaining to N, P and K uptake by grain and straw as influenced by varieties and fertility treatments are presented in Table 4.8. Interaction between varieties and fertility
levels had non significant effect on N, P and K uptake by grain and straw.

**4.6.1 Nutrient (N, P and K) uptake (Kg ha\(^{-1}\)) by grain**

Both the varieties had significant effect on nutrient uptake by grain, except K uptake by grain. The maximum (26.23, 3.08 and 8.81 Kg ha\(^{-1}\)) N, P and K uptake was recorded by variety HUM-16.

Data in Table 4.8 revealed that among the fertility levels, F\(_2\) (75% RDF + Rhizobium + PSB + 25% N through FYM) had the maximum (29.89, 3.42 and 10.13 Kg ha\(^{-1}\)) N, P and K uptake by grain.

**4.6.2 Nutrient (N, P and K) uptake (Kg ha\(^{-1}\)) by straw**

Perusal of data in the Table 4.8 showed that the nutrient uptake by straw was significantly influenced due to varieties. The maximum (26.83, 4.21 and 61.56 Kg ha\(^{-1}\)) and the minimum (25.56, 4.12 and 59.61 Kg ha\(^{-1}\)) value of N, P and K uptake by straw were recorded in variety HUM-16 and HUM-12, respectively.

Analysis of data in Table 4.8 clearly revealed that N, P and K uptake by straw significantly influenced by fertility levels. The fertility level F\(_2\) (75% RDF + Rhizobium + PSB + 25% N through FYM) and F\(_4\) (No application) were recorded the maximum (30.76, 4.54 and 68.44 Kg ha\(^{-1}\)) and the minimum (21.25, 3.80 and 51.99 Kg ha\(^{-1}\)) N, P and K uptake by straw.

**4.7 Available N, P and K in soil (Kg ha\(^{-1}\))**

Data regarding available N, P and K status in soil recorded after harvest of the crop are presented in Table 4.9. Variations in available N, P and K status due to varieties were non significant except available P in soil.
Available nitrogen, phosphorus and potassium significantly influenced by different fertility levels. The maximum (186.81, 14.13 and 146.15 Kg ha\(^{-1}\)) amount of available N, P and K in soil after harvest of crop recorded in fertility level F\(_2\) (75% RDF + Rhizobium + PSB + 25% N through FYM). The fertility level F\(_3\) (50% RDF + Rhizobium + PSB + 50% N through FYM) was statistically at par with F\(_1\) (100% RDF) in case of available P in soil. Interaction effect between varieties and fertility levels were non significant.

**4.8 Economics**

The data pertaining to the economics as influenced by variety and fertility levels are presented in Table 4.10.

The data indicated that the variety HUM-16 recorded maximum gross return (69944.13), net return (49051.13), cost of cultivation (20893) and B: C ratio (2.35) which was higher than the gross return (68728.09), net return (48167.09), cost of cultivation (20561) and B:C ratio (2.34) of the variety HUM-12.

Perusal of data in Table 4.10 clearly indicate that fertility level F\(_3\) (50% RDF + Rhizobium + PSB + 50% N through FYM) incurred the maximum (20895) cost of cultivation followed by F\(_1\) (20415) and F\(_2\) (20120) whereas, the fertility level F\(_2\) (75% RDF + Rhizobium + PSB + 25% N through FYM) was recorded higher gross return (77015.01), net return (56895.01) and B: C ratio (2.83). The fertility level F\(_4\) (No application) recorded least gross return (57692.62), net return (39136.62) and B: C ratio (2.11).
Table 4.1: Effect of varieties and fertility levels on plant height (cm) of green gram.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Plant height (cm)</th>
<th></th>
<th></th>
<th></th>
</tr>
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<tr>
<td><strong>Variety</strong></td>
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<td></td>
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</tr>
<tr>
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<td>33.97</td>
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</tr>
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<td></td>
<td></td>
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S.Em. ± indicates the standard error of the mean.
Table 4.2: Effect of varieties and fertility levels on number of trifoliate leaves plant$^{-1}$ of green gram.

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Table 4.3: Effect of varieties and fertility levels on number of branches plant$^{-1}$ and number of nodules plant$^{-1}$ of green gram.

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<th>Treatment</th>
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<th>Number of nodules plant$^{-1}$</th>
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Table 4.4: Effect of varieties and fertility levels on dry matter accumulation (g plant\(^{-1}\)) of green gram.

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<td>2.29</td>
<td>7.55</td>
<td>12.31</td>
<td>12.47</td>
</tr>
<tr>
<td>F(_4)</td>
<td></td>
<td>1.47</td>
<td>5.68</td>
<td>8.70</td>
<td>8.84</td>
</tr>
<tr>
<td>S. Em. ±</td>
<td></td>
<td>0.09</td>
<td>0.21</td>
<td>0.26</td>
<td>0.26</td>
</tr>
<tr>
<td>CD (P= 0.05)</td>
<td></td>
<td>0.26</td>
<td>0.65</td>
<td>0.79</td>
<td>0.79</td>
</tr>
<tr>
<td>CV (%)</td>
<td></td>
<td>9.86</td>
<td>7.20</td>
<td>5.74</td>
<td>5.36</td>
</tr>
<tr>
<td>Interaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Non significant</td>
</tr>
</tbody>
</table>
Table 4.5: Effect of varieties and fertility levels on yield attributes of green gram.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield attributes</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of Pods plant⁻¹</td>
<td>Pod length (cm)</td>
<td>Number of Grains pod⁻¹</td>
<td>1000-grain weight (g)</td>
</tr>
<tr>
<td>Variety</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HUM-12</td>
<td>9.93</td>
<td>7.63</td>
<td>9.44</td>
<td>25.73</td>
</tr>
<tr>
<td>HUM-16</td>
<td>9.96</td>
<td>8.07</td>
<td>9.64</td>
<td>25.93</td>
</tr>
<tr>
<td>S.Em. ±</td>
<td>0.11</td>
<td>0.10</td>
<td>0.10</td>
<td>0.14</td>
</tr>
<tr>
<td>CD (P= 0.05)</td>
<td>NS</td>
<td>0.29</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Fertility level</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F₁</td>
<td>10.03</td>
<td>7.62</td>
<td>9.54</td>
<td>26.02</td>
</tr>
<tr>
<td>F₂</td>
<td>10.90</td>
<td>8.51</td>
<td>10.07</td>
<td>27.16</td>
</tr>
<tr>
<td>F₃</td>
<td>10.23</td>
<td>7.82</td>
<td>10.04</td>
<td>26.34</td>
</tr>
<tr>
<td>F₄</td>
<td>8.60</td>
<td>7.45</td>
<td>8.53</td>
<td>23.82</td>
</tr>
<tr>
<td>S.Em. ±</td>
<td>0.16</td>
<td>0.13</td>
<td>0.14</td>
<td>0.20</td>
</tr>
<tr>
<td>CD (P= 0.05)</td>
<td>0.48</td>
<td>0.41</td>
<td>0.43</td>
<td>0.62</td>
</tr>
<tr>
<td>CV (%)</td>
<td>3.87</td>
<td>4.20</td>
<td>3.65</td>
<td>1.93</td>
</tr>
<tr>
<td>Interaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non significant</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4.6: Effect of varieties and fertility levels on grain, straw yield (Kg ha\(^{-1}\)) and harvest index (%).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Grain Yield (Kg ha(^{-1}))</th>
<th>Straw Yield (Kg ha(^{-1}))</th>
<th>Harvest Index (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Variety</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HUM-12</td>
<td>805.93</td>
<td>2536.55</td>
<td>23.79</td>
</tr>
<tr>
<td>HUM-16</td>
<td>829.35</td>
<td>2641.04</td>
<td>24.00</td>
</tr>
<tr>
<td>S.Em. ±</td>
<td>13.96</td>
<td>32.84</td>
<td>0.17</td>
</tr>
<tr>
<td>CD (P= 0.05)</td>
<td>NS</td>
<td>99.60</td>
<td>NS</td>
</tr>
<tr>
<td><strong>Fertility level</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F(_1)</td>
<td>822.09</td>
<td>2597.89</td>
<td>23.71</td>
</tr>
<tr>
<td>F(_2)</td>
<td>978.71</td>
<td>2965.24</td>
<td>24.83</td>
</tr>
<tr>
<td>F(_3)</td>
<td>892.74</td>
<td>2851.68</td>
<td>23.85</td>
</tr>
<tr>
<td>F(_4)</td>
<td>577.02</td>
<td>1940.38</td>
<td>23.19</td>
</tr>
<tr>
<td>S.Em. ±</td>
<td>19.74</td>
<td>46.44</td>
<td>0.24</td>
</tr>
<tr>
<td>CD (P= 0.05)</td>
<td>59.88</td>
<td>140.86</td>
<td>0.73</td>
</tr>
<tr>
<td>CV (%)</td>
<td>5.91</td>
<td>4.39</td>
<td>2.47</td>
</tr>
<tr>
<td>Interaction</td>
<td></td>
<td></td>
<td>Non significant</td>
</tr>
</tbody>
</table>
Table 4.7: Effect of varieties and fertility levels on N, P and K content (%) in grain and straw of green gram.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Content (%) in grain</th>
<th>Content(%) in straw</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
</tr>
<tr>
<td>Variety</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HUM-12</td>
<td>3.60</td>
<td>3.41</td>
</tr>
<tr>
<td>HUM-16</td>
<td>3.65</td>
<td>3.50</td>
</tr>
<tr>
<td>S.Em. ±</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>CD (P= 0.05)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fertility level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F₁</td>
<td>3.59</td>
<td>3.41</td>
</tr>
<tr>
<td>F₂</td>
<td>3.76</td>
<td>3.74</td>
</tr>
<tr>
<td>F₃</td>
<td>3.70</td>
<td>3.51</td>
</tr>
<tr>
<td>F₄</td>
<td>3.46</td>
<td>3.16</td>
</tr>
<tr>
<td>S.Em. ±</td>
<td>0.04</td>
<td>0.05</td>
</tr>
<tr>
<td>CD (P= 0.05)</td>
<td>0.14</td>
<td>0.15</td>
</tr>
<tr>
<td>CV (%)</td>
<td>3.02</td>
<td>3.45</td>
</tr>
<tr>
<td>Interaction</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non significant</td>
<td></td>
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</tbody>
</table>
Table 4.8: Effect of varieties and fertility levels on N, P and K uptake (Kg ha\(^{-1}\)) by grain and straw of green gram.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Uptake (Kg ha(^{-1})) by grain</th>
<th>Uptake (Kg ha(^{-1})) by straw</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
</tr>
<tr>
<td>Variety</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HUM-12</td>
<td>24.50</td>
<td>2.92</td>
</tr>
<tr>
<td>HUM-16</td>
<td>26.23</td>
<td>3.08</td>
</tr>
<tr>
<td>S.Em. ±</td>
<td>0.45</td>
<td>0.03</td>
</tr>
<tr>
<td>CD (P=0.05)</td>
<td>1.37</td>
<td>0.08</td>
</tr>
<tr>
<td>Fertility level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F(_1)</td>
<td>23.83</td>
<td>2.96</td>
</tr>
<tr>
<td>F(_2)</td>
<td>29.89</td>
<td>3.42</td>
</tr>
<tr>
<td>F(_3)</td>
<td>27.49</td>
<td>3.16</td>
</tr>
<tr>
<td>F(_4)</td>
<td>20.25</td>
<td>2.46</td>
</tr>
<tr>
<td>S.Em. ±</td>
<td>0.64</td>
<td>0.04</td>
</tr>
<tr>
<td>CD (P= 0.05)</td>
<td>1.93</td>
<td>0.11</td>
</tr>
<tr>
<td>CV (%)</td>
<td>6.15</td>
<td>3.08</td>
</tr>
<tr>
<td>Interaction</td>
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</table>
### Table 4.9: Effect of varieties and fertility levels on available N, P and K (Kg ha$^{-1}$) in post harvest soil.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Available N (Kg ha$^{-1}$)</th>
<th>Available P (Kg ha$^{-1}$)</th>
<th>Available K (Kg ha$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Variety</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HUM-12</td>
<td>170.77</td>
<td>12.87</td>
<td>141.17</td>
</tr>
<tr>
<td>HUM-16</td>
<td>171.31</td>
<td>13.28</td>
<td>141.21</td>
</tr>
<tr>
<td>S.Em. ±</td>
<td>0.45</td>
<td>0.13</td>
<td>0.27</td>
</tr>
<tr>
<td>CD (P= 0.05)</td>
<td>NS</td>
<td>0.39</td>
<td>NS</td>
</tr>
<tr>
<td><strong>Fertility level</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F$_1$</td>
<td>171.63</td>
<td>13.16</td>
<td>138.36</td>
</tr>
<tr>
<td>F$_2$</td>
<td>186.81</td>
<td>14.13</td>
<td>146.15</td>
</tr>
<tr>
<td>F$_3$</td>
<td>176.72</td>
<td>13.49</td>
<td>144.38</td>
</tr>
<tr>
<td>F$_4$</td>
<td>149.01</td>
<td>11.51</td>
<td>135.87</td>
</tr>
<tr>
<td>S.Em. ±</td>
<td>0.64</td>
<td>0.18</td>
<td>0.39</td>
</tr>
<tr>
<td>CD (P= 0.05)</td>
<td>1.93</td>
<td>0.55</td>
<td>1.18</td>
</tr>
<tr>
<td>CV (%)</td>
<td>0.91</td>
<td>3.41</td>
<td>0.67</td>
</tr>
<tr>
<td>Interaction</td>
<td></td>
<td></td>
<td>Non significant</td>
</tr>
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</table>
Table 4.10: Effect of varieties and fertility levels on economics of crop cultivation.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost of Cultivation (( ))</th>
<th>Gross return (( ))</th>
<th>Net return (( ))</th>
<th>B:C ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Variety</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HUM-12</td>
<td>20561</td>
<td>68728.09</td>
<td>48167.09</td>
<td>2.34</td>
</tr>
<tr>
<td>HUM-16</td>
<td>20893</td>
<td>69944.13</td>
<td>49051.13</td>
<td>2.35</td>
</tr>
<tr>
<td><strong>Fertility level</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F_{1}</td>
<td>20415</td>
<td>69545.65</td>
<td>49130.65</td>
<td>2.41</td>
</tr>
<tr>
<td>F_{2}</td>
<td>20120</td>
<td>77015.01</td>
<td>56895.01</td>
<td>2.83</td>
</tr>
<tr>
<td>F_{3}</td>
<td>20895</td>
<td>73091.18</td>
<td>52196.18</td>
<td>2.50</td>
</tr>
<tr>
<td>F_{4}</td>
<td>18556</td>
<td>57692.62</td>
<td>39136.62</td>
<td>2.11</td>
</tr>
</tbody>
</table>
Fig. 4.1 Effect of varieties and fertility levels on yield attributes of Green gram.

(a) Pod length (cm)

(b) 1000-grain weight (g)
Fig. 4.2 Effect of varieties and fertility levels on grain, straw yield (kg ha\(^{-1}\)) and harvest index (%).

(a) 

(b)
Plate 3: Green gram 40 DAS under custard apple based agri-horti system.

Plate 4: Green gram at podding stage under custard apple based agri-horti system.
Plate 1: Green gram at 30 DAS under custard apple based agri-horti system.

Plate 1: Custard apple fruit at 60 DAS of green gram crop under custard apple based agri-horti system.
DISCUSSION

Experimental findings of the study entitled “Effect of varieties and fertility levels on growth and yield of green gram (Vigna radiata L.) in custard apple (Annona squamosa L.) based agri-horti system under rainfed condition” have been presented in the preceding chapter in detail. In this chapter an attempt has been made to evaluate the important observations recorded during the course of investigation in terms of cause and effect relationship. Economic yield, which is produced by a crop is the cumulative function of growth and development parameters, size of the photosynthetic system and its efficiency, duration and translocation of photosynthetic to economic sink. Yield per unit area is the cumulative function of yield plant$^{-1}$. Yield plant$^{-1}$ is the function of number of pods plant$^{-1}$, number of grain pod$^{-1}$ and test weight. There are some growth parameters, which contribute indirectly to yield. These characters are affected by physiological and metabolic processes, which are modified by environmental conditions, fertilizer application and other cultural practices. The variation in yield has been analyzed in terms of differences in yield components. The findings of earlier workers on the subject have also been taken in to consideration, while discussing the result of present investigation. The discussion is presented under various heads.

5.1 Effect of weather

Weather plays an important role in crop production especially under rainfed condition. 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) 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, vapour 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. Green gram requires fairly hot conditions during growth to produce maximum yield and generally grown as rainy 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 3.1) recorded during the crop season showed that the average temperature was within the optimum range (24.9-31.4°C) for growth of green gram. The rainfall received (1080 mm) during the study was low but well distributed and during the maturity phase occurrence of dry weather supported the growth and yield of crop.
5.2 Effect of varieties on growth, yield and yield attributes of green gram

The yield of a crop is result of the successful completion of the growth and development activities in individual plant, which in turn, would depend upon genetic potential of the variety and the environmental conditions. Real potential of the variety could be exploited to its maximum with several agronomic manipulations which alters the micro-environment of a crop.

The total dry matter production in variety indicates the potential for yield. The capacity of a plant to produce dry matter depends upon the size and duration of the photosynthetic apparatus, i.e. leaf, which depends upon the genetic potential of the varieties and capability to translocate the assimilates towards economic yield.

The present study the results showed that HUM-16 recorded comparatively higher values of growth attributes viz. plant height, number of trifoliate leaves, number of branches, number of nodules and dry matter accumulation than HUM-12. The variety HUM-16 observed higher grain and straw yield, this might be due to its inherited genetic makeup as evidenced by comparatively higher number of pod plant\(^{-1}\), pod length, number of grains pod\(^{-1}\) and test weight. Differential response of different varieties was also observed in black gram by Mahto and Mahto (1997) and Prabhakar and Ganapathy (1996).

5.3 Effect of fertility levels on growth, yield and yield attributes of green gram

The finding of the present study indicate that growth attributes of crop such as plant height, number of trifoliate leaves, number of branches, number of nodules and dry matter
accumulation had marked variation under various fertility levels. The growth attributes had higher values with F2 (75% RDF + Rhizobium + PSB + 25% N through FYM) as compared to F4 (no application) Yadav et al. (2007) reported that PSB and Rhizobium had positive effect on growth and yield attributes. The increase in growth attributes under F2 (75% RDF + Rhizobium + PSB + 25% N through FYM) fertility level could be assigned due to increased cell division on one hand due to sufficient supply of nitrogen and phosphorus by dual inoculation of Rhizobium and PSB.

The root nodules plant⁻¹ was observed significantly enhanced with the medium and recommended dose of fertilizers under dual inoculation of Rhizobium and PSB as compared to their uninoculation during all the observation periods. It was due to higher number of bacteria present under inoculated condition than uninoculated plots. PSB inoculation might have more availability of phosphorus in which favored better root growth and resulted in a beneficial effect on nodulation with increased Rhizobium bacterial activity. The results were in close conformity with the observations recorded by Tarafdar et al. (1992).

Dry matter accumulation increased markedly with dual inoculation with Rhizobium and PSB under the medium level of fertility. This influence of treatment may be attributed to higher microbial population favoring more N contents (%) and its association with increased chlorophyll formation due to Rhizobium inoculation and increased phosphatase activity (that increased phosphorus supply to plants ) and the beneficial effects on production of growth regulators due to PSB.
inoculation. The similar reasons were also proposed by Prasad and Ram (1984) and Tarafdar et al. (1992).

Yield attributes, which determine yield, is the resultant of the vegetative development of the plant. All the attributes of yield viz., number of pods plant$^{-1}$, pod length, number of grains pod$^{-1}$ and 1000 grain weight were maximum under fertility level F$_2$ (75% RDF + *Rhizobium* + PSB + 25% N through FYM). Yield attributing characters are function of growth during vegetative phase of the plant. The reason for increased number of pods plant$^{-1}$ in F$_2$ (75% RDF + *Rhizobium* + PSB + 25% N through FYM) attributed to increased number of branches and dry matter accumulation.

Yield is the result of co-ordinate interplay of yield attributes viz., number of pod plant$^{-1}$, pod length, number of grains pod$^{-1}$ and 1000 grain weight.

The grains pod$^{-1}$ and test weight was improved due to different fertility treatments. The maximum number of pods plant$^{-1}$, straw yield and 1000-grain weight was recorded in fertility level F$_2$ (75% RDF + *Rhizobium* + PSB + 25% N through FYM) followed by F$_3$ (50% RDF + *Rhizobium* + PSB + 50% N through FYM) and F$_1$ (100% RDF). This could be attributed to better supply of nitrogen and phosphorus with the biofertilizers resulting in higher branches and pods and there by higher yield. It is an established fact that phosphorus plays an important role in the formation of new shoots thereby, increases the number of branches plant$^{-1}$. Khan and Kounsar (2000) and Perveen et al. (2002) also observed the similar type of results in their experiments.
5.4 Nutrient contents and uptake

In the present study the results showed none significant variations in nutrient contents in grain and straw due to varieties. However, fertility levels gave significant effect in nutrient contents in grain and straw. Among fertility levels the F$_2$ (75% RDF + *Rhizobium* + PSB + 25% N through FYM) recorded higher nutrient content over rest of the fertility levels. The inoculation of seed with *Rhizobium* and PSB increased the nitrogen, phosphorus and potassium contents in grain as well as straw. This might be due to more nitrogen fixation by the bacteria which in turn helped in better absorption and utilization of plant nutrients, thus resulting in more N and P contents in grain and straw.

The nutrient uptake is an integrated function of soil-crop environment, together with amounts and sources nutrient supply and cultivars of the crop. The term uptake denotes the net movement of mineral from the ambient to the plant and numerically is a product of nutrient concentration and yield. The nutrient uptake is a relative term depending upon the test plants, its duration as well as its population density and management. The above conformity by Hoshiyar *et al.* (1994) and Das *et al.* (1997).

The varieties had significant effect on nutrient uptake except K and N uptake by grain and straw, respectively. However the fertility levels showed significant improvement in nutrient uptake by grain and straw.

The N uptake by grain and straw of green gram were affected significantly by *Rhizobium* inoculation. It was due to higher dry matter accumulation and nitrogenase activity under
Rhizobium inoculation which beneficially improved bacterial population in Rizosphere which in turn improved N- uptake by grain and straw. Rhizobium inoculation fixes nitrogen through nodules of the plant whereas PSB solubilizes native P rendering more phosphorus to soil solution. Thus, combined inoculation of grain with Rhizobium and PSB improved N, P and K status of soil and ultimately increased N, P and K uptake. Nitrogen, phosphorus and K uptake by the plant increased considerably with corresponding increase in nitrogen, phosphorus and potassium levels. Similar finding were also reported by Khan, et al. (2008) and Ara et al. (2009) with respect to nitrogen and phosphorus.

**5.5 Available NPK in the soil**

The varieties had non significant effect on available nutrient in soil except available P. Fertility level F₂ (75% RDF + Rhizobium + PSB + 25% N through FYM) significantly increased the available nitrogen, phosphorus and potassium in the soil over rest of the fertility levels after harvest of crop. This can be attributed that higher level of fertility (75% RDF + Rhizobium + PSB + 25% N through FYM) resulted in better nitrogen fixation by Rhizobium bacteria from the atmosphere slow release of phosphorus to the crop from the native source through activities of PSB inoculation and applied nitrogen and phosphorus which slowly resulted in more buildup of the nitrogen and phosphorus in the soil.

**5.6 Relative economics**

The data on relative economics of various treatments revealed that the maximum net return and B: C ratio were
recorded under $F_2$ (75% RDF+ *Rhizobium* +PSB+25% N through FYM) with variety HUM-16 as compared to $F_4$ (No application) with variety HUM-12. This is due to fact that $F_2$ (75% RDF+ *Rhizobium* +PSB+25% N through FYM) increased the grain yield gross return, and net return.
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 conclusions based on the significant findings of the present investigation entitled “Effect of varieties and fertility levels on growth and yield of green gram (Vigna radiata L.) in custard apple (Annona squamosa L.) based agri-horti system under rainfed condition”. The investigation was conducted during rainy (kharif) season of 2011 at the Agricultural Research Farm of Rajiv Gandhi South Campus, Banaras Hindu University, Barkachha, Mirzapur.

The soil of the experimental field was sandy loam in texture and medium acidic soil reaction (pH 5.6). It was moderately fertile, being low in organic carbon (0.27%), low in available nitrogen (183.67 kg ha⁻¹), and medium in available phosphorus (11.25 kg ha⁻¹) and medium in available potassium (125.8 kg ha⁻¹). The experiment was laid out in Factorial Randomized Block Design with agri-horti system (fruit based agroforestry system) viz., custard apple based agri-horti system. Treatments were replicated thrice. The experiment comprises 8 treatment combination viz. HUM-12 + 100% RDF, HUM-12 + 75% RDF + Rhizobium + PSB + 25% N through FYM, HUM-12 + 50% RDF + Rhizobium + PSB + 50% N through FYM, HUM-12 + No application, HUM-16 + 100% RDF, HUM-16 + 75% RDF + Rhizobium + PSB + 25% N through FYM, HUM-16 + 50% RDF + Rhizobium + PSB + 50% N through FYM and HUM-16 +
No application. The requisite quantity of seed at the rate of 20 kg for green gram was sown. The seed were sown with help of *kudal* directly in rows 30 x 10 cm apart. The experiment was carried out with six years old custard apple trees planted at 5 x 5 meter spacing.

Crop response to the treatments were measured in term of various quantitative indices, *viz.*, plant height, number of nodules plant⁻¹, number of trifoliate leaves plant⁻¹, number of branches plant⁻¹, dry matter accumulation plant⁻¹, yield components *viz.*, number of pods plant⁻¹, grains pod⁻¹, 1000-grain weight, grain and straw yields, and uptake of the nutrient (N, P and K). Soil was analyzed for available nitrogen, phosphorus and potassium at initiation of the experiment and after the harvest of the green gram. The data collected during the course of experimentation were subjected to statistical analysis to draw valid conclusion. Finally the different treatments were analyzed for their gross return, net return and benefit: cost ratio. The important findings and broad conclusions emerging from the investigation are summarized as under.

1. Plant height increased with the advancement of crop age and reached to its maximum at maturity. Green gram variety HUM-16 recorded taller than HUM-12. Variations in plant height were observed with fertility levels at all the crop growth stages. The taller plant height was obtained with the F₂ (75% RDF + *Rhizobium* + PSB + 25% N through FYM) and the smallest with F₄ (No application).

2. The number of trifoliate leaves plant⁻¹ increased up to 60 days after sowing. The minimum and the maximum number of trifoliate leaves plant⁻¹ obtained in HUM-12 and
HUM-16 respectively. Among fertility treatment the maximum number of trifoliate leaves plant$^{-1}$ obtained in F$_2$ (75% RDF + *Rhizobium* + PSB + 25% N through FYM) followed by F$_3$ (50% RDF + *Rhizobium* + PSB + 50% N through FYM) and F$_1$ (100% RDF).

3. Number of branch plant$^{-1}$ increased with advancement of crop age and reached to its maximum at maturity, the minimum and the maximum number of branch plant$^{-1}$ was recorded with the variety HUM-12 and HUM-16, respectively. The maximum number of branches plant$^{-1}$ was observed in fertility treatment F$_2$ (75% RDF + *Rhizobium* + PSB + 25% N through FYM) followed by F$_3$ (50% RDF + *Rhizobium* + PSB + 50% N through FYM), F$_1$ (100% RDF) and F$_4$ (No application).

4. The maximum root nodules was recorded in variety HUM-16 with fertility treatment F$_2$ (75% RDF + *Rhizobium* + PSB + 25% N through FYM) at 40 days after sowing.

5. Dry matter accumulation plant$^{-1}$ increased with advancement in crop age till maturity. The HUM-16 observed higher dry matter accumulation plant$^{-1}$ than HUM-12. The maximum and the minimum dry matter accumulation plant$^{-1}$ was observed with fertility level F$_2$ (75% RDF + *Rhizobium* + PSB + 25% N through FYM) and F$_4$ (No application), respectively throughout the crop growth period.

6. The yield attributes viz., number of pods plant$^{-1}$, pod length, number of grain pod$^{-1}$ and 1000 grain weight were recorded higher in variety HUM-16 with fertility level F$_2$
(75% RDF + *Rhizobium* + PSB + 25% N through FYM), whereas the variety HUM-12 with F_4 (no application) observed comparatively little improvement in yield attributes than variety HUM-16 with fertility level F_2. Interaction between varieties and fertility levels had non significant effect on yield attributes.

7. As regards the green gram varieties, HUM-16 produced higher grain and straw yields followed by HUM-12. The maximum grain and straw yields was observed in fertility treatment F_2 (75% RDF + *Rhizobium* + PSB + 25% N through FYM) followed by F_3 (50% RDF + *Rhizobium* + PSB + 50% N through FYM), F_1 (100% RDF) and F_4 (No application).

8. HUM-16 had better dry matter partitions as compared to HUM-12. The fertility treatment F_2 (75% RDF + *Rhizobium* + PSB + 25% N through FYM) was recorded the maximum harvest index followed by F_3 (50% RDF + *Rhizobium* + PSB + 50% N through FYM), F_1 (100% RDF) and F_4 (No application).

9. The available nitrogen, phosphorus and potash in soil after the harvest of crop improved markedly under fertility treatment F_2 (75% RDF + *Rhizobium* + PSB + 25% N through FYM).

10. The maximum and the minimum gross return was obtained from HUM-16 with fertility treatment F_2 (75% RDF + *Rhizobium* + PSB + 25% N through FYM) and F_4 (no application). The maximum net return and benefit:cost
ratio were also obtained from F₂ (75% RDF + *Rhizobium* + PSB + 25% N through FYM).

**Conclusion**

On the basis of experimental findings, the following conclusions may be drawn:

1. The variety HUM-16 was found more suitable as compared to HUM-12 under agroclimatic conditions of Vindhyan region of India.

2. Application of 75% RDF + 25% N through FYM and double inoculation with *Rhizobium* and PSB was found more remunerative fertilization practices under present study.

The present study was conducted for one year, more trials needs to be conducted to ascertain these findings.


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**APPENDICES**

Apendix-I: Growth parameter of Custard apple tree at sowing.

<table>
<thead>
<tr>
<th>Fruit tree species</th>
<th>Height (meter)</th>
<th>Canopy diameter (meter)</th>
<th>Stem girth (cm)</th>
<th>Shading area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Custard apple</td>
<td>2.79</td>
<td>2.91</td>
<td>30.10</td>
<td>5.56</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.60</td>
</tr>
</tbody>
</table>

Apendix-II: Growth parameter of Custard apple tree at crop harvest.

<table>
<thead>
<tr>
<th>Fruit tree species</th>
<th>Height (meter)</th>
<th>Canopy diameter (meter)</th>
<th>Stem girth (cm)</th>
<th>Shading area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Custard apple</td>
<td>3.05</td>
<td>3.26</td>
<td>31.09</td>
<td>5.93</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.85</td>
</tr>
</tbody>
</table>

Apendix- III: Yield attributes, yield and economic of custard apple tree.

<table>
<thead>
<tr>
<th>Fruit tree</th>
<th>No. of average fruits tree(^{-1})</th>
<th>Average weight of fruit (gm.)</th>
<th>Number of fruit tree ha(^{-1})</th>
<th>Fruit yield (kg ha(^{-1}))</th>
<th>Rate of fruit (Rs/Kg)</th>
<th>Gross income from fruit tree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Custard apple</td>
<td>32.5</td>
<td>80</td>
<td>400</td>
<td>1040</td>
<td>28</td>
<td>29000</td>
</tr>
</tbody>
</table>
### Appendix-VI: Common cost of cultivation (` ha⁻¹)

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Operations</th>
<th>Input</th>
<th>Rate (')</th>
<th>Cost ('')</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Land preparation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(i) One deep ploughing by soil turning plough</td>
<td>One tractor (35 HP) for 2.5 hrs</td>
<td>310/ha</td>
<td>775</td>
</tr>
<tr>
<td></td>
<td>(ii) Harrowing and planking</td>
<td>One tractor (35 HP) for 4 hrs</td>
<td>310/ha</td>
<td>1240</td>
</tr>
<tr>
<td>2.</td>
<td>Layout</td>
<td>5 labour/day</td>
<td>195/labour</td>
<td>975</td>
</tr>
<tr>
<td>3.</td>
<td>Seed sowing</td>
<td>6 labour/day</td>
<td>195/labour</td>
<td>1170</td>
</tr>
<tr>
<td>4.</td>
<td>Thinning and Weeding</td>
<td>9 labour/day</td>
<td>195/labour</td>
<td>1755</td>
</tr>
<tr>
<td>5.</td>
<td>Weeding (Custard apple)</td>
<td>6 labour/day</td>
<td>195/labour</td>
<td>1170</td>
</tr>
<tr>
<td>6.</td>
<td>Harvesting and Threshing</td>
<td>20 labour/day</td>
<td>195/labour</td>
<td>3900</td>
</tr>
<tr>
<td>7.</td>
<td>Harvesting fruit (Custard apple)</td>
<td>16 labour/day</td>
<td>195/labour</td>
<td>3120</td>
</tr>
<tr>
<td>8.</td>
<td>Land revenue</td>
<td>For 6 months</td>
<td>120/annum</td>
<td>60.00</td>
</tr>
<tr>
<td>9.</td>
<td>Interest on working capital</td>
<td>For 6 months</td>
<td>4.4%/annum</td>
<td>891.45</td>
</tr>
</tbody>
</table>

**Total** 15056.45