EFFECT OF FERTILITY LEVELS AND COW URINE ON GROWTH, YIELD AND QUALITY OF INDIAN MUSTARD [*Brassica juncea* (L.) Czernj. & Cosson]

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

Master of Science (Agriculture)
in
Agronomy

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Submitted by
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CERTIFICATE

To,
The Registrar
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Through: **The Head,** Department of Agronomy

Dear Sir,

I have great pleasure in forwarding the thesis entitled **"Effect of fertility levels and cow urine application on growth, Yield and quality of Indian mustard [*Brassica juncea (L.) Czernj. & Cosson*]"** submitted by **Ms. Surajyoti Pradhan**, **I.D. No. A-13011,** in partial fulfillment of the requirements for the degree of **Master of Science (Agriculture)** in **Agronomy**, of the Banaras Hindu University and placing on record that she has completed the requisite requirements as contained in the statutes of the university.

I certify that the entire scheme of investigation reported herein was planned and carried out solely by the candidate under my guidance and supervision. The data presented in the thesis, to the best of my knowledge and belief, are genuine and have not been utilized for the award of other degree or distinction.

Yours faithfully

FORWARDED: **(Prof. J.S. Bohra)**

Head   **Supervisor**

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"A dream doesn't become reality through magic; it takes sweat, determination and hard work." —Colin Powell

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Let us make these words of Mahamana as our ideal – "I do not for a royal realm aspire, for release or for paradise. To serve those bent with grief I desire, and calm their sorrows and help them rise."

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INTRODUCTION

Oilseeds play a vital role in Indian economy, accounting for 5% of gross national product and 10% of the value of agricultural product. In India, oilseeds are the second largest agricultural commodity after cereals, which occupy about 13.5% of the gross cropped area in the country. India is the fourth largest oilseed economy in the world after the U.S., China and Brazil, and it is the second largest importer after china (Anonymous 2014). The country accounts for 15 per cent of global oilseeds area, 7 per cent of vegetable oils production and 10 per cent of the total edible oils consumption (Jha *et al.*, 2012). Rapeseed-mustard is the third important oilseed crop in the world after soybean (*Glycine max*) and palm (*Elaeis guineensis* Jacq.). Among the seven edible oilseeds cultivated in India, rapeseed-mustard (*Brassica* spp.) contributes 28.6% to the total production of oilseeds. It ranks second in oilseeds production after groundnut, sharing 27.8% in the India's oilseed economy.

Rapeseed- mustard oil is considered to be an important constituent of Indian diet and its oil is used as main cooking medium especially in northern India. Both the seed and oil are used as condiment in the preparation of pickles and flavoring curries and vegetables. Apart from these oil is also utilized for preparation of hair oils, medicines and soaps. The cake obtained after the oil extraction is mostly used as cattle feed and manure. Green stem and leaves are a good source of fodder for cattle. The leaves of young plants are used as green vegetables as they supply enough sulphur and minerals in the diet. In tanning industry, mustard oil is used for softening of leather.

In 'Rape seed and Mustard' group of oil seeds, mustard [*Brassica juncea* (L.) Czernj. & Cosson] occupies the prime position in India. Mustard is predominantly cultivated in Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh, and Gujarat. It is also grown under some nontraditional areas of South India including Karnataka, Tamil Nadu, and Andhra Pradesh. It is cultivated both under irrigated (79.2%) and rainfed (20.8%) conditions. Indian mustard accounts for about 75-80% of the 5.8 m ha of rapeseed and mustard with the productivity of 1142 kg ha^{-1} in the country. Mustard seed has 36% protein content with a high nutritive value. The oil content varies from 37 to 42 %. It is a winter (*Rabi*) season crop that requires relatively cool temperature, a fair supply of soil moisture during the growing season and a dry harvest period (Banerjee *et al.*, 2010).

The country witnessed yellow revolution through a phenomenal increase in production and productivity of rapeseed and mustard from 2.68 m t and 650 kg/ha in 1985-86 to 6.96 m t and 1022 kg/ha in 1996-1997, respectively. In spite of these achievements, there exists a gap between production potential and actual realization. In India rapeseed-mustard is grown on an area of 5.53 m ha with production and productivity of 6.41 m t and 1157 kg/ha. In spite of increased production and productivity of rapeseed-mustard in the country, the per capita consumption (8.2 kg capita^{-1} year^{-1}) of fats and oils is quite low. The requirements of fats and oils will be much higher in view of increasing population and improved and increased standard of living of the people in near future.

All the major nutrients viz. Nitrogen, phosphorus potassium and sulphur play important role in increasing the yield and quality of mustard. Nitrogen is known to activate most of metabolic activities and transformation of energy. Phosphorus is essential for cell division and meristematic growth of tissue. It also helps in seed and fruit development and it stimulates flowering as well. Adequate potassium results in superior quality of the whole plant due to the improved efficiency of photosynthesis, increased resistance to some diseases and greater water use efficiency. Potassium helps in maintaining a normal balance between carbohydrates and proteins. Sulphur application greatly influences chlorophyll synthesis, carbohydrate as well as protein metabolism and finally results in improvement in growth characters, contributing to higher dry matter accumulation in plants Willenbrink, (1967). It has been experimentally found that, in cauliflower cultivation the highest curd yield and the highest benefit cost ratio were observed by application of N through urine.(Khanal *et al*., 2011).

However, the productivity of oilseeds is now slowing down coupled with decline in soil fertility. Low and imbalanced use of fertilizers is one of the major reasons for low productivity. It has been recognized that N, P and K fertilizers alone are not always sufficient to provide balanced nutrition for optimal yield and quality of mustard (Jain and Sharma, 2000). The chemicals give an immediate effect on crop production for small duration but creates long term ill effects on both ecosystem and soil health. Intensive use of chemical fertilizers and other chemicals has produced environmental problems and increased production costs.

The exploitative agriculture for centuries in our country has brought down the fertility status of the soil to a level that even the application of fertilizers at higher rates is unable to sustain the productivity of soil. Therefore, in order to sustain the productivity and promote the health of the soil combined use of organic and chemical fertilizers is imperative.

On one hand chemical fertilizers alone do not provide all the nutrients in balanced quantities needed by the plants and on the other hand encourage depletion of soil organic matter content, adversely affect biological and physical properties of soil, also their increasing prices, soil health deterioration, sustainability and pollution consideration in general have led to renewed interest in the use of organic manures. The Use of organic manure not only helps to sustain crop yields but also plays a key role by exhibiting both direct as well as indirect influence on the nutrient availability in soil by improving the physical, chemical and biological properties of soil and also improves the use efficiency of applied fertilizers (Singh and Biswas, 2000).

The escalating price of fertilizers in recent years, limit their use in crop production. Therefore, the nutrient application through chemical fertilizers, if supplemented with low cost organic sources will not only economize the nutrient use but also improve the soil health and factor productivity on sustainable basis.

Crop + dairy is the predominant farming system in the country practiced by over 70 % farm households. The abundant quantity of cattle excreta consisting of dung and urine is available. Though part of cattle dung is used as manure but major quantity of urine goes waste. However, cattle urine has a good manurial value and can be utilized as a bio fertilizer. (Ledgard *et al.*, 1982; Khanal *et al.*, 2011 and Singh *et al.*, 2012). Cattle urine is a good source of nitrogen, phosphate, potassium, calcium, magnesium, chlorite and sulphate (Belie *et al.* 2000). Application of cow urine has also been reported to correct the micronutrient deficiency, besides improving the soil texture and working as a plant hormone.

Therefore, it seems that cow urine under livestock based integrated farming system has a great potential for use as a bio fertilizer in crop production.

So that Crop production could be economized. This will also improve the fertilizer use efficiency as well as the soil health. With these facts in view, a field trial was conducted to explore the possibility of economizing fertilizer use in mustard by partial replacement of fertilizer through cow urine as bio-fertilizer.

Keeping in view the all above facts, the present experiment entitled " Effect of fertility levels and cow urine application on growth , yield, and quality of Indian mustard [*Brassica juncea* (L.) Czernj. & Cosson]" was planned and carried out during 2013 -14 at the Institute of Agricultural Sciences, B.H.U. , Varanasi with the following objectives :

1. To study the effects of fertility and cow urine levels on growth, yield and quality of Indian mustard.
2. To study the treatment effect on nutrient uptake.
3. To work out the economics of various treatments.

Chapter II

REVIEW OF LITERATURE

Mustard is the most important oilseed crops for edible oil in northern India. In the last few years, the yield levels of mustard are either declining or stagnating because of appreciable decline in the organic matter level and fertility of soils all over the country. In this direction, it is the need of the hour to lay emphasis on application of adequate quantities of plant nutrients a key aspect of increasing productivity of different crops particularly in the areas where farmers following intensive agriculture. In this regard, the available literature on **"Effect of fertility levels and cow urine application on growth, yield, and quality of Indian mustard [*Brassica juncea* (L.) Czernj. & Cosson]"** is presented in this chapter under the following headings.

2.1 EFFECT OF NITROGEN

2.1.1 Effect of nitrogen on growth parameters

Growth of plant is perhaps most significantly controlled by deficiency of nitrogen than any other macro element derived from soil. Nitrogen has direct effect on growth and yield attributes of rapeseed and mustard. Application of nitrogen in right amount and right time remarkably enhances the yield of Indian mustard, as this crop is exhaustive in nature and requires more energy for its proper growth and development.

Singh and Saran (1987) reported that application of nitrogen to *toria* improved the plant growth in terms of plant height, primary branches plant^{-1} and dry matter accumulation. Increasing levels of nitrogen application up to 90 kg N ha^{-1} markedly improved the values of these growth characters.

Rathore and Manohar (1989) found that increase in rate of nitrogen application from 30 to 180 kg N ha^{-1} enhanced the number of branches and dry matter production plant^{-1} as compare with untreated plot of *Brassica juncea*.

Nepalia *et al.* (1990) observed that application of nitrogen up to 60 kg N ha^{-1} increased plant height, dry matter plant^{-1} and leaf area index of Indian rape(*Brassica* *compestris* var Toria). Nitrogen application at the rate of 60 kg N ha^{-1} significantly increased the plant height, leaf area index and primary and secondary branches in mustard (Joshi *et al.*1991). Similarly, Agrawal and Gupta (1991) working on mustard found increase in plant height and number of branches plant^{-1} with corresponding increase in nitrogen levels up to 60 kg N ha^{-1}.

Chauhan *et al.* (1993) conducted experiment on sandy loam soil with low organic matter content at Gurgaon. It was observed that application of 60 kg N resulted marked increase in plant height, primary branches plant^{-1} of Indian mustard over 40 kg N ha^{-1}.

Padmini *et al.* (1994) conducted a study on Indian mustard (*Brassica juncea*) to assess the influence of nitrogen; they reported that increase in nitrogen application rate from 30 to 60 kg N ha^{-1} resulted in improvement in leaf area index(LAI), net assimilation rate (NAR) and crop growth rate (CGR) of plants. Similarly, Shukla and Kumar (1993) found that application of N increased CGR, LAR, and LAI while RGR decreased at higher N rates. Yadav *et al.* (1994) found increased leaf water potential, stomatal conductance, light absorption and leaf area index with increase in nitrogen application in mustard.

Petal and Meisher (1996) performed a field experiment during 1992-94 at Anand (Gujarat), on loamy sand soil with low organic C and N and medium available P &K having pH-7.9. Nitrogen application @ 75 kg N increased plant height, primary and secondary branches as compared to 25 kg N ha^{-1}. The result confirms the finding of Mohan and Sharma (1992).

Tomar *et al.* (1997) carryout field experiment during 1991-92 at (Haridwar) on sandy loam soil, poor in total N, available P, medium K and organic C with pH 7.7 of soil. It was found that nitrogen levels increased the plant height, branches plant^{-1} and dry matter accumulation plant^{-1} with increase in the level of nitrogen, up to 120 kg N ha^{-1}.

Bhari *et al.* (2000) evaluating the effect of N levels (30, 60, 90, and 120 kg N ha^{-1}) on Indian mustard var. ‘Varuna’ reported that application of N up to 120 kg ha^{-1} resulted in significant increase in plant height, primary and secondary branches and siliquae plant^{-1} which was at par with 90 kg N ha^{-1} in respect of growth attributing characters.

Tripathi and Tripathi (2003) carried out an experiment to investigate the effect of N levels (80, 120 160 and 200 kg ha^{-1}) on growth, yield and quality of Indian mustard. The result revealed that plant height, leaf-area index, dry-matter accumulation plant^{-1}, primary and secondary branches plant^{-1} increased with increasing N levels up to 160 kg ha^{-1}.

Maurya *et al.* (2004) conducted an experiment in Bahraich, Uttar Pradesh, to study the effect of N fertilizer (0, 50, 100 and 150 kg ha^{-1}) on high-yielding Indian mustard cultivars Vardan, Varuna and Pusa Bold. Pusa Bold fertilized with 150 kg N ha^{-1} gave the highest germination percentage while Vardan with 150 kg N ha^{-1} showed maximum plant height and number of branches per plant.

Thanki *et al.* (2004) conducted a field experiment in Gujarat, Indian mustard cv. 'Gujarat Mustard-1'. Plants were supplied with 25, 50 or 70 kg N ha^{-1}, 0, 25 or 50 kg P ha^{-1} and 0 or 10 t farmyard manure ha^{-1}. Plant height, number of branches per plant, number of siliquae per plant, 1000-seed weight, seed yield, oil yield and net returns were increased, whereas oil content decreased with increasing rates of N. The values for all the parameters measured were highest with the application of 50 kg P ha^{-1} and 10 kg farmyard manure ha^{-1}. N, P and K uptake increased with increasing rates of N, P and farmyard manure.

Dongarkar (2005) conducted a field experiment at Nagpur, Maharashtra, during 2003-2004 to study the effect of four levels of nitrogen (0, 25, 50, 75 kg ha^{-1}) and three levels of sulfur (0, 20, 40 kg ha^{-1}) in mustard (*Brassica juncea*). It was recorded that the application of 75 kg N ha^{-1} over 25 kg N ha^{-1} significantly influenced the growth of mustard. Plant height, number of branches, dry matter production, number of siliquae were increased up to 75 kg N over control but at par with 50 kg N ha^{-1}.

Sah *et al.* (2006) observed that plant height and primary branches plant^{-1} significantly increased up to 80 kg N ha^{-1}, while secondary branches, dry matter plant^{-1}and leaf chlorophyll content increased up to 120 kg N ha^{-1}.

Kumar (2007) carried out investigation on Indian mustard *var.* 'Vardan' during 2003-2004 to find out the growth potential with varying nitrogen and sulphur levels. It was observed that application of 80 kg N ha^{-1} had significantly increased all the growth parameters e.g. (plant height, number of branches, number of leaves, leaf area and number of primary, secondary and tertiary branches).

Kumar *et al.* (2007) conducted a field trial in Narson, Uttar Pradesh, to study the growth performance of mustard (*B. juncea*) at different N levels (0, 40, 80 and 120 kg/ha). It was recorded that the number of branches per plant, number of leaves per plant, leaf area index, dry matter accumulation per plant and growth rate were significantly increased with the increasing level of N up to 120 kg N ha^{-1}.

Kumar and Kumar (2008) performed a field experiment on 'Vardan' variety of Indian mustard during 2003-2004 to study the effect of various doses of nitrogen (0, 60, 80, 100, 120 and 140 kg ha^{-1}) and sulphur (0, 20, 40 and 60 kg ha^{-1}) on crop growth rate and various developmental characters. The results indicated that 50% flowering started significantly earlier in the plots fertilized with nitrogen and sulphur compared to the control plot but the days to attain maturity were not affected by fertilization. The seed growth duration was significantly longer by 9 days for fertilized plots compared to control. However, crop growth rates at different stages of growth were not affected by fertilizer application.

Dawson *et al*. (2009) reported that the highest plant height and maximum plant dry weight was recorded with the application 100 kg N ha^{-1} over 80 kg.

Zimik *et al.* (2010) conducted an experiment to study the effect of nitrogen levels (50, 75 and 100 kg ha^{-1}) on growth of mustard. The result revealed that the leaf area (LA), leaf area index (LAI), net assimilation rate (NAR), plant growth efficiency (E), yield efficiency rate (YER), dry matter percentage (DM%) and vegetable yield improved significantly up to 100 kg N ha^{-1}.

2.1.2 Effect of nitrogen on yield attributes and yield

Singh and Saran (1987) reported that application of nitrogen up to 90 kg N ha^{-1} to Indian rape *(B. campestris var. toria)* grown in sandy loam soil improved yield attributes *viz.*, siliquae plant^{-1} and 1000-seed weight but the differences among the various N levels were not significant.

Experiment conducted on mustard at Jobner, Rajasthan, revealed that the yield and number of siliqua plant^{-1} significantly increased with increasing levels of nitrogen application up to 120 kg N ha^{-1}. However, optimum dose of nitrogen application was worked out as 147.5 and 166.8 kg N ha^{-1} during 1984-85 and 1985-86, respectively (Rathore and Manohar, 1989).

On sandy loam soil at Varanasi, Singh *et al* (1998) reported that seed and stover yield, removal of nitrogen, phosphorus and potassium significant increased with increasing levels of nitrogen up to 80 kg N ha^{-1} under rainfed condition. Maximum seed (WUE_s), biomass (WUE_b) and net return were also recorded with 80 kg N ha^{-1}.

Singh *et al.* (1993) performed an experiment at Hissar, during 1991-92 on sandy loam soil with slightly alkaline in reaction, low in organic carbon and available N. It was found that Indian mustard var. RH 30 gave significantly higher seed yield, test weight and harvest index content than 'Varuna' with application of 120 kg N ha^{-1}.

Dubey and Khan (1993) in a study on mustard variety 'Varuna', found significant response of nitrogen application. The seed yield significantly increased with increasing levels of Nitrogen up to 90 kg N ha^{-1}. The increase in the seed yield was 75.21, 164.53 and 223.08 per cent owing to 30, 60 and 90 kg N ha^{-1}, respectively over no nitrogen.

Chauhan and Paroda (1993) carried out field experiment at Gurgaon (Haryana) on sandy loam soil, low in organic C and available N and it was observed that nitrogen application at 80 kg N ha^{-1} recorded markedly higher values of growth and yield attributes and seed yield of raya except 1000 seed weight. Similar response to N application has also been reported by Rathore and Manohar (1989) and Singh and Saran (1997).

Thakuria and Gogoi (1994) conducted field experiment at Jorhat (Assam), during 1989-91. The soil was sandy loam in texture with acidic reaction (pH 4.8). It was found that application of 80 kg N ha^{-1} significantly increased seed yield and yield attributes in both the years. Similar findings have also been reported by Vir and Verma (1981), Singh and Singh (1987) and Singh and Singh (1991).

Aulakh *et al*. (1995) reported that application of 0, 50, 100 and 150 kg N ha^{-1} to *B. campestris* var. sarson cv GSL-1 resulted in significant increase in seed yield up to 100 kg N $ha^{-1.}$ However Das and Das (1995) obtained that the highest yield of *toria* with 90 kg N ha^{-1}.

Mahal *et al.* (1995) working on *toria* at Ludhiana found significant increase in seed yield up to 120 kg N ha^{-1} with a response of 6-7 kg seed per kg N. They further reported that at 120 kg N ha^{-1} the seed yield was maximum with two irrigation.

Ali *et al.* (1996) working on rapeseed reported from Dhaka, Bangladesh that increasing levels of nitrogen up to 120 kg N ha^{-1} improved the yield components viz. siliquae m^{-2} and seeds $siliqua^{-1}$. It also enhanced seed and stover yield as well as harvest index. Similarly, Singh *et al*., (1996) obtained the highest seed yield of mustard at 120 kg N ha^{-1}. Arthamwar *et al.* (1996) found a linear increase in seed yield of mustard due to increase in nitrogen levels from 0-100 kg N ha^{-1}.

Mahal *et al.* (1996) conducted field experiment during 1992 and 1993 at Ludhiana. It was found that application of nitrogen @ 90 kg N ha^{-1} significantly increased the total siliquae $plant^{-1}$, 1000-seed weight, seed yield and oil content over 60 kg N ha^{-1} while it remained at par with 120 kg N ha^{-1}.

Shahidullah *et al.* (1996) working on mustard (*Brassica juncea*) cv. Kalyani, Sonali, Daulat and Tori-5 and Nitrogen levels (0, 75, 00, 125 and 150 kg N ha^{-1}) found that seed yield increased up to 100 kg N ha^{-1} and maximum yield was noted with var. Sonali.

Deekshitula *et al.* (1997) found that the number of siliquae $plant^{-1}$, 1000-seed weight and N uptake increased significantly up to 150 kg N ha^{-1}, while the number of seeds $siliqua^{-1}$ increased significantly only up to 100 kg N ha^{-1}. However, Kumar *et al.* (1997) reported that the highest LAI, dry matter and yield were obtained with 150 kg N ha^{-1}. Singh *et al.* (1997) in a field trail at Ludhiana, working on *Brassica juncea* cv. RLM 619 reported that the seed yield were comparable at 125 and 150 kg N but both levels produced significantly higher seed yield than 100 kg N ha^{-1}.

Akhtar and Bohra (2000) reported that siliqua plant^{-1}, test weight, seed yield, stover yield as well as output-input ratio were increased with increasing levels of N application up to 90 kg ha^{-1}. Application of 60 kg N ha^{-1} under rainfed condition resulted in significant increase in siliqua plant^{-1}, test weight and seed yield. However, Singh and Kumar (1996) and Bhan and Singh (1976) reported marked improvement in seed yield, number of siliqua plant^{-1} and number of seeds siliqua^{-1} with the application of nitrogen. Significant increase in seed yield of mustard was obtained with every increment in the level of N up to 120 kg ha^{-1}. Meena and Sharma (2002) found that application of 60 kg N registered significantly higher seed and stover yield of mustard over the control 30 kg N but it remained statistically at par with 90 kg N ha^{-1}.

Dhaka and Satish (2003) and Jain *et al*. (2002) observed that seed and stover yields enhanced with increasing N rates up to 80 kg N ha^{-1}, while integration of P_2O_5 and N produced higher yield as compared to 80 kg N ha^{-1}alone.

Prein and Kumar (2004) reported that significant increase in number of siliquae plant^{-1} up to 120 kg N ha^{-1} and number of seeds siliqua^{-1} up to 80 kg N ha^{-1} which resulted significant increase in seed yield up to 120 kg N ha^{-1}. Nitrogen levels did not affect siliqua length and test weight of mustard.

Singh and Sinsinwar (2005) conducted field experiment at Bharatpur (Rajasthan) on sandy loam soil. All the yield attributes were significantly increased with increasing levels of nitrogen up to 80 kg N ha^{-1}, which ultimately resulted in significant increase in grain yield.

Kumar *et al.* (2010) observed that application of 80 kg N/ha and 45 kg S ha^{-1}significantly increased the seed yield with concomitant increase in growth and yield attributes. The per cent increase in seed yield at 80 kg N ha^{-1}over 60, 40 and 20 kg N were 2.4, 12.0 and 15.5. Increasing levels of nitrogen and sulphur appreciably improved yield attributes (plant height, branches plant^{-1}, dry matter accumulation, siliquae plant^{-1}, seeds siliquae^{-1}, seed and stalk yield). The uptake of N and S significantly increased up to highest rate of 80 kg N and 45 kg S ha^{-1}, respectively.

Singh (2010) conducted a field experiment during 2004-2005 and 2005-2006 to study the response of Indian mustard *Brassica juncea* to nitrogen and sulfur levels under rainfed conditions. Application of 80 kg N ha^{-1} and 45 kg S ha^{-1} significantly increased the seed yield with concomitant increase in growth and yield attributes. Increasing levels of nitrogen and sulfur appreciably improved the growth characters, yield attributes (plant height, branches $plant^{-1}$, dry matter accumulation, siliquae $plant^{-1}$, seeds $siliquae^{-1}$, seed and stalk yield) and protein content. Similarly, Mohiuddin *et al.* (2011) reported that the siliquae $plant^{-1}$, seed and stover yield increased with increasing Nitrogen levels up to 80 kg N ha^{-1}. Further increase in N level i.e. 120 kg N ha^{-1} had a negative effect on seed yield.

2.1.3 Effect of nitrogen on nutrient content and uptake

The concentration of nitrogen in seed of mustard has been found to increase progressively with increasing levels of N application (Gupta *et al.*, 1972 and Aulakh *et al.*, 1980). Similarly, increased seed N content, N and P uptake and apparent recovery of applied N due to 60 kg N ha^{-1} in rainfed mustard has been reported by Vir and Verma (1979).

In clay soil of low fertility at Udaipur, Bhati and Rathore (1982) working on Indian mustard observed significant influence of nitrogen application on nitrogen content of seed and stover. They noted the highest nitrogen uptake with application of 60 kg N ha^{-1}. Whereas, with increasing rate of N application up to 120 kg N ha^{-1} has been reported by Patil and Bhargava (1987). Similarly increased nitrogen content in seed and stover as well as N uptake by *Oliferous Brassica* due to increasing rates of N were reported by Singh and Saran (1987), Rathore and Manohar (1990) and Nuttal and Malhi (1991).

A field experiment conducted on *Brassica* species in sandy loam soil at Hissar in Haryana revealed that N and P concentration in seed and stover were increased correspondingly with increasing rate of nitrogen application up to 120 kg N ha^{-1} (Singh *et al.*, 1993). However, N, P and K uptake increased up to 80 kg N ha^{-1}. Similarly, Dubey and Khan (1993) recorded increase in N content and uptake due to nitrogen application up to 90 kg N ha^{-1}. Das and Das (1994) also reported increase in N, P, and S uptake in seed with increasing nitrogen rate up to 90 kg N ha^{-1}.

In field experiment Dubey *et al.* (1994) found that nitrogen application up to 90 kg N ha^{-1} increased N and S content and uptake in mustard seed, whereas, Kumar *et al.* (1995) observed significant improvement in nitrogen content and uptake up to 60 kg N ha^{-1}.

According to Kakati and Kalita (1996) and Shukla and Kumar (1997) nitrogen concentration as well as uptake of rapeseed and mustard increased with increasing rates of N application up to 120 kg N ha^{-1}. Similarly, Patel *et al.* (1998) noticed that 0, 25, 50 or 75 kg N ha^{-1} applied to mustard enhanced the contents of N and S as well as N, P, and S uptake.

2.1.4 Effect of nitrogen on quality parameters

The oil percentage in seed and quality are greatly influenced by fertilizers use. Among the major plant nutrients, nitrogen has been found to play a key role in determining the oil accumulation in seeds of *Brassica*. Nevertheless, experiments conducted on the influence of nitrogen have shown marked variations in results. Oil content in particular, has shown erratic response to nitrogen application, though, majority of studies indicate a depressing effect of nitrogen in oil content of seed, particularly at higher rates.

Dubey and Khan (1993) at Powerkheda, Madhya Pradesh, working on mustard variety ‘Varuna’, found decline in seed oil percentage with increasing levels of nitrogen application up to 90 kg N ha^{-1}. However, the reduction was significant only up to 60 kg N ha^{-1}. Nitrogen content of seed, which also indicates the seed protein content, was negatively correlated with nitrogen application.

Arora *et al.* (1994) working with Indian mustard reported that oil content and iodine value increased with increasing rates of nitrogen from 0 to 90 kg N ha^{-1}. While Thakral *et al.* (1996) observed that oil content decreased by increasing levels of N. However, Iodine value, protein and glucosinolate content were increased. Similar results were also obtained by Kabati *et al*. (1996) with the application of 0-100 kg N ha^{-1}. Kumar *et al*. (1995) observed that oil content in *Brassica* genotypes declined with increasing levels of nitrogen application up to 90 kg N ha^{-1}. However, oil yield increased. Decrease in oil content by increasing N levels has also been reported by Ali *et al.* 1996.

Thakral *et al.* (1996) working with *Brassica spp*. observed that oil content decreased by increasing levels of N. However, iodine value, protein and glucosinolate content were increased. Similar result was also obtained by Kabati *et al*. (1996) with application of 0-100 kg N ha$^{-1.}$ Ahmed *et al.* (1998) found that application of S and N with increasing rates resulted increase in oil yield and maximum oil yield was found with 100 kg N and 60 kg S ha^{-1}. Singh *et al.* (1998) noticed that the application of 120 kg N and 9.2 kg S ha^{-1} resulted significant increase in the protein and oil content of Indian mustard.

Dhaka and Kumar (2003) observed that oil content decreased due to increasing N rate. While the trend was reverse for protein content. However, Meena and Symeriya (2003) reported the highest oil content (37.04%) with application of 60 kg N ha^{-1}, while 90 kg N ha^{-1} resulted in maximum protein content (21.55%). Premi and Kumar (2004) observed that oil content in mustard seed significantly decreased with increase in N levels up to 80 kg ha^{-1}. Nevertheless Singh *et al.* (2004) found that N application did not influence the oil content in mustard but oil yield and chlorophyll content were increased up to 90 kg N ha^{-1}.

Singh *et al.* (2010) reported that mean plant height, total dry matter accumulation, leaf area and seed yield were higher when 100% recommended fertilizers (120, 40, 20, 40 kg N, P,K, S ha^{-1}) were applied along with Farmyard manure (FYM) at 10 t ha^{-1}, $ZnSO_4$ (25 kg ha^{-1}) and seed treatment with *Azotobacter*. Mean seed yield of mustard with this treatment increased by 41.2% over application of recommended fertilizers. More application of fertilizer increased protein content but reduced the glucosinolate content in seed. Oil content decreased at higher inorganic fertility levels it was improved with application of FYM and *Azotobacter* .

Singh *et al.* (2010) found that the quality parameters like oil and protein content in seed and their yield were influenced significantly by various fertility levels. Oil content increased significantly with increasing fertility levels up to 100% RDF and thereafter decreased with increase in fertility. However, protein content increased with increasing in fertility level and recorded the highest value at 150% RDF.

2.2 EFFECT OF PHOSPHORUS

2.2.1 Effect of phosphorus on growth parameters

Pareek *et al.* (1999) carried out a field experiment during 1996-97 on loamy sand soil at Jobner, Rajasthan, to investigate the effect of phosphorus, sulfur and phosphate solubilizing bacteria (PSB, *Pseudomonas radiata*) on the growth and yield of mustard [*Brassica juncea*] cv. Bio 902. Application of 15 kg P_2O_5 ha^{-1} significantly increased plant height but the number of primary and secondary branches were higher with 30 kg P_2O_5 ha^{-1}.

Chaubey *et al.* (2001) performed a field experiment on an Entisol of Ujhani (U.P.) to evaluate the response of mustard (*Brassica juncea* cv. Rohini) to phosphorus (0, 40 and 60 kg P_2O_5 ha^{-1}) fertilization. It was reported that with the increasing level of P and S up to 60 kg P_2O_5 and 30 kg S ha^{-1}, respectively there was significant increased in growth parameters i.e. (Plant height, number of branches $Plant^{-1}$).

Davaria, *et al.* (2001) carried out field experiment at Junagadh, Gujarat. The treatments comprised P_2O_5 at 0, 25, and 50 kg ha^{-1}. In the P treatments, numbers of primary branches $plant^{-1}$ (6.9), secondary branches per plant (12.6), siliquae per plant (278) and seeds per siliqua (12.1), 1000-seed weight (3.54 g), seed yield (15.43 q ha^{-1}), and stover yield (39.44 q ha^{-1}) were highest with 50 kg P_2O_5 ha^{-1}. It was further observed that application of 50 kg P_2O_5 ha^{-1} significantly increased leaf chlorophyll content as well as P and S contents of seeds.

Kantwa and Meena (2002) reported from Jobner, Rajasthan that, the application of phosphorus up to 45 kg P_2O_5 ha^{-1}significantly increased the growth parameters.

Indian mustard cv. ‘Gujarat Mustard-1’ plants were supplied with 25, 50 or 70 kg N, 0, 25 or 50 kg P and 0 or 10 t FYM ha^{-1} in a field experiment conducted in Gujarat. The values of growth parameters viz. plant height and branches per plant were highest with the application of 50 kg P_2O_5 $ha^{-1}$and 10 kg FYM ha^{-1} [Thanki *et al.* (2004)].

Bohra *et al.* (2006) conducted an experiment during the *rabi* season of 1997-98 at Varanasi, to study the growth and nutrient uptake patterns of Indian mustard (*Brassica juncea*) at various levels of N, P and S. Application of P up to 60 kg ha^{-1}

significantly enhanced dry matter per plant but plant height, branches per plant and leaf chlorophyll content increased significantly only up to 40 kg P ha^{-1}. Similarly, Singh *et al.* (2008) conducted a field study during 2003-04 in Uttar Pradesh, to evaluate the effect of P (0, 20, 40 and 60 kg ha^{-1}) levels on the performance of Indian mustard cv. 'Varuna'. A linear increase in final plant height, number of functional leaves/plant, siliquae/plant, were observed with application of 60 kg P ha^{-1}.

Khatkar *et al.* (2009) performed a field experiment during 2004-2005 at Agricultural Research Farm, Allahabad. The experiment consisted of three factors namely nitrogen (80 and 100 kg ha^{-1}) and sulphur (10, 20 and 30 kg ha^{-1}), phosphorus (40 and 60 kg ha^{-1}) with blanket application of potash at 40 kg ha^{-1}. Significantly higher plant dry weight was recorded at 60 kg P_2O_5 ha^{-1}. Also, more number of siliquae $plant^{-1}$, seed $siliqua^{-1}$ and the test weight was also recorded with higher levels of these factors which ultimately resulted in higher seed yield.

On sandy loam soil, Sahu and Sah (2011) reported that the plant height, primary branches per plant, leaf area index, dry matter accumulation per plant, crop growth rate and relative growth rate of Indian mustard increased significantly up to 50 kg P_2O_5 ha^{-1} and 40 kg S ha^{-1}.

2.2.2 Effect of phosphorus on yield attributes and yield

Working on Indian mustard Patel *et al.* (1999) reported that application of P significantly increased the yield parameters, seed and Stover yield, oil and protein content up to 80 kg P ha^{-1}. However, Sharma *et al.* (2001) found that the seed and straw yield significantly increased with increasing levels of P up to 60 kg P_2O_5 ha^{-1}.

Singh *et al.* (1999) reported that seed yield increased with up to 100 kg N (1.66 t ha^{-1}) and 30 kg P (1.41 t ha^{-1}). However, Bhari *et al.* (2000) noted that P application up to 45 kg P ha^{-1} resulted in significant increase in secondary branches and siliquae $plant^{-1}$ only up to 45 kg P_2O_5 ha^{-1}.

Jat *et al.* (2000) reported that number of siliquae $plant^{-1}$, number of seeds $siliqua^{-1}$ and seed yield significantly increased with the highest level of P (40 kg ha^{-1}), however, harvest index was not affected to the level significance by P application. However, Jakhar and Singh (2004) recorded significant increase in dry matter accumulation plant^{-1} and plant height with the residual effect of 40 kg P ha^{-1}applied in preceding crop.

Pareek *et al.* (1999) carried out a field experiment on loamy sand soil at Jobner, Rajasthan, to investigate the effect of phosphorus, sulfur and phosphate solubilizing bacteria (PSB, *Pseudomonas radiata*) on the growth and yield of mustard [*Brassica juncea*] cv. Bio 902. Application of 15 kg P_2O_5 ha^{-1} significantly increased dry matter accumulation, number of siliqua plant^{-1}, seeds siliqua^{-1}, length of siliqua and test weight over the control (no P). However, the seed and straw yields were increased upto 30 kg P_2O_5 ha^{-1}.

Sumeriya *et al.* (2003) conducted experiment at Jobner, Rajasthan, on mustard grown at Mloamy sand soil. The application of phosphorus fertilizer at 60 kg ha^{-1} significantly increased the yield parameters. The highest number of siliquae plant^{-1}, seeds siliquae^{-1} and seed yield were obtained with 60 kg P_2O_5 ha^{-1}.

Saxena *et al.* (2005) conducted an experiment during 2002-03 in Uttar Pradesh, to study the effects of phosphorus and iron on the growth, yield and oil content of Indian mustard (*Brassica juncea*) cv. 'Varuna' treatments comprised 0 and 40 kg P_2O_5 ha^{-1}; and 0, 15 and 30 kg Fe ha^{-1}. Application of 40 kg P_2O_5 ha^{-1}recorded higher number of branches plant^{-1}, siliquae plant^{-1}, seed yield plant^{-1} and oil content than control. Rana *et al.* (2005) conducted a field experiment at IARI New Delhi, to study the effects of 3 phosphorus levels (0, 25 and 50 kg P_2O_5 ha^{-1}), on rainfed Indian mustard (*Brassica juncea* cv. Pusa Barani). Progressive increase in P levels increased the yield attributes and seed yield, but the increase in seed yield was significant only up to 25 kg P_2O_5/ha.

Giri *et al.* (2006) carried out an experiment on mustard variety 'Pusa bold' at Nagpur, Maharashtra, during 2003-04 to study the effect of phosphorus and sulfur application on growth and yield of *Brassica juncea*. Application of 50 kg P ha^{-1} recorded significantly higher seed yield (13.47 q ha^{-1}) as compared to other levels of phosphorus.

Singh *et al.* (2007) reported marked improvement in yield attributes as well as seed and stover yields of Indian mustard with progressive increase in phosphorus levels up to 60 kg P ha^{-1}. He conducted a field study during 2003-04 in Uttar Pradesh, to evaluate the effect of P (0, 20, 40 and 60 kg ha^{-1}/ha) levels on the performance of Indian mustard cv. Varuna. A linear increase in siliquae $plant^{-1}$, seed yield, total dry matter content and stover yield ware observed with application of 60 kg P ha^{-1}.

Mir *et al*., (2010) reported that the optimum effect of the application of 60 kg P_2O_5 ha-1 on seed yield was presumably due to maximum pods/plant, seed/pod and seed weight, as these parameters were found to be positively correlated with yield of the crop. The seed yield and oil yield increased by application of fertilizers 60 kg P_2O_5 ha-^{1}.

2.2.3 Effect of phosphorus on nutrient content and uptake

Gupta *et al.* (1972) working on Indian mustard obtained non-significant improvement in seed and stover P content with increasing P application rates. They further recorded more concentration on P in seed than stover. Rajput *et al.* (1994) noted that increasing phosphorus levels significantly reduced N content in husk and stem. However, the uptake of N, P and K by seed significantly enhanced with application of 80 kg P_2O_5 ha^{-1}. Similarly, the P and S content of soyabeen increased with increasing levels of P_2O_5 from 0 to 80 kg ha^{-1} but N content increase upto 120 kg P_2O_5 ha^{-1} (Aulakh *et al.*, 1995). Jain *et al.* (1995) applied 20, 40 and 60 kg P_2O_5 ha^{-1} to mustard and observed significant increase in N, P, K and S uptake of seed and stover up to 40 kg P_2O_5 ha^{-1}.

2.2.4 Effect of phosphorus on quality parameters

Thanki *et al.* (2004) conducted a field experiment in Gujarat, during 1995-98 on Indian mustard cv. Gujarat Mustard-1, it was observed, the oil yield increase with the application of 50 kg P/ha and 10 kg FYM ha^{-1}.

Saxena *et al.* (2005) conducted an experiment during 2002-03 in Uttar Pradesh, to determine the effects of phosphorus and iron on the growth, yield and oil content of Indian mustard (*Brassica juncea*) cv. 'Varuna'. They observed that the application of 40 kg P ha^{-1} recorded significantly higher seed yield and oil content than without P.

Bhat *et al*. (2006) reported that oil content decreased with increasing N and P rates. Although the extent of decrease in seed oil content was lower than increase in seed yield and thus the total edible oil yield was still higher with higher fertilizer rates compared to the normal recommended rates of fertilizer.

Faujdar *et al.* (2008) conducted an experiment with four levels of P (0, 20, 40 and 60 kg/ha) and four levels of S (0, 20, 40 and 60 kg ha^{-1}) to determine the yield and quality of Indian mustard. They reported that application was beneficial in increasing, oil content and oil yield, protein content, chlorophyll content as well as S-containing amino acids in seeds. However, Lone *et al.* (2010)**,** reported that oil content increased with increasing P levels (0, 30 and 60 kg ha^{-1}) but beyond this level i.e., 90 kg P ha^{-1} showed no considerable increase in oil content.

2.3 EFFECT OF POTASSIUM

2.3.1 Effect of Potassium on growth attributes

In a field experiment Mukherjee (1990) applied 0, 20, 40 and 60 kg K_2O ha^{-1} to mustard cv. T 59 and rapeseed cv. B 9 and reported significant increase in LAI, CGR, dry matter, was with 40 kg K_2O ha^{-1}. In another study, Ghosh *et al.*, (1993) recorded a response of 3.73 kg mustard seeds per kg of K_2O added irrespective of the status of K in the soils

Bhati and Sharma (2006) studying the influence of K and its time of application on leaf area index (LAI) and chlorophyll content of mustard found that application of K @ 60 kg K ha^{-1} significantly increased LAI over control at 45 DAS. Potassium application also significantly increased chlorophyll content at 45 and 90 DAS.

Cheema *et al*., (2012) carried out a field study was to assess the influence of different levels of K fertilization (0, 30, 60, 90,120 kg ha^{-l}) on two canola cultivars viz. Bulbul-98 and Zafar-2000. Results revealed that increasing rate of K enhanced leaf area index and crop growth rate in both cultivars.

2.3.2 Effect of potassium on yield attributes and yield

Prasad and Chuhan (1999) observed that greater K in plants improved the carbohydrate metabolism and hence yield. They also reported that the application of

N: P (100: 50 and NPK (100: 50: 50) significantly increased the shoot hill^{-1}, effective shoot hill^{-1} and plant height than control in rice.

Khan *et al*., (2004) carried out Studies to assess the influence of different levels of potassium fertilization (0, 25, 50, 75, 100, 125 & 150 kg ha-1) on seed yield of canola. The results revealed that the highest seed yield at highest level K; however, it remained at par with treatments 50, 75, 100 and 125 kg K ha-^{1}. While minimum seed yield was recorded in case of control i.e. with no K.

Fanaei *et al.,* (2009) reported that with increasing potassium application rates, negative effect of water stress on grain yield was ameliorated and seed yield improved. Results of this study showed that potassium application can positively affect seed yield and water use efficiency of rapeseed and Indian mustard under severe and mild stress conditions. It is concluded that potassium application was effective on plant growth and formation of economic yield by ameliorating damages caused due to water stress.

A field experiment was carried out by Mozaffari *et al*., (2012) at Qazvin-Iran during 2009-2010 to assess the effect of different levels potassium (K_0, K_{45}, K_{90} and K_{135} kg ha^{-1}) on yield and some of the agronomical characteristics in Mustard (*Brassica juncea*). The results showed that increasing levels of Potassium up to 135 kg K ha^{-1} had a significant effect on seed oil percentage (SOP) and harvest index (HI)

Cheema *et al*., (2012) carried out a field study was to assess the influence of different levels of K fertilization (0, 30, 60, 90,120 kg ha^{-l}) on two canola cultivars viz. Bulbul-98 and Zafar-2000. Highest seed yield (3067.24 kg ha^{-l}) was obtained when K was applied at 120 kg ha^{-l}. While minimum seed yield (2353.85 kg ha^{-l}) was recorded in case of control.

2.3.2 Effect of potassium on nutrient content and uptake

Tiwari et al., (2012) investigated the effect of five levels of potassium viz. 0, 20, 40, 60 and 80 K_2O kg ha^{-1} applied as muriate of potash on mustard. Potassium content in seed and stover increased with the use of K over the control. The removal of K increased as yield increased, up to 194 kg K_2O ha^{-1}. Similarly, K content increased in seed (from 0.88 to 0.99 percent) but there was no marked effect on stover K content .The removal of K increased mainly by the increased yield, up to a level of 184 kg K_2O ha^{-1}.

2.3.3. Effect of potassium on quality parameters

Khan *et al*., (2004) carried out Studies to assess the influence of different levels of potassium fertilization (0, 25, 50, 75, 100, 125 and 150 kg ha^{-1}) on oil contents of canola. The highest seed yield was obtained with K @ 150 kg ha^{-1}, which was however, at par with treatments where 50, 75, 100 and 125 kg K ha^{-1} were applied. While lowest seed yield was recorded in case of control i.e. without K. However, Oil content progressively decreased with increase of K level with highest (42.86%) in case of control and lowest (37.42%) with a K level of 150 kg ha^{-1}.

At Kanpur *Tiwari et al*., (2012) while studying the response mustard to five levels of potassium at(0, 20, 40, 60 and 80 K_2O kg ha^{-1}) applied as muriate of potash observed that, increasing doses of potassium up to 60 kg K_2O ha^{-1} significantly increased seed and stover yields of mustard. Likewise, protein and oil content were also increased significantly by K application. Similar results showing the benefit of K on crop yield have also been reported by Prasad *et al.* (1993).

Paliwal and Singh (2014) conducted a field experiment to evaluate response of mustard (*Brassica juncea* L. Czernj. and Cosson) to potassium in combination with other nutrients on yield and quality was conducted at Govind Ballabh Pant University of Agriculture and Technology, Pantnagar during *Rabi* season of 2012-13. Protein yield (306 kg ha^{-1}) and oil yield (736 kg ha^{-1}) were recorded maximum at 150% NPK level.

2.4 EFFECT OF FERTILITY LEVELS

2.4.1 Effect of fertility levels on growth parameters

Fertility management with high dose of nutrients (80 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1}) irrespective of their sources, caused appreciable improvement in growth attributes viz. plant height, functional leaves and dry matter of rapeseed cv. B-9 (Pradhan et al., 1997).

Chaudhary *et al.* (2003) investigated the effect of N, P, K and Zn on the growth and yield attributes of Indian mustard at Kanpur, Uttar Pradesh. He found that the application of N at 30 kg + P at 20 kg+ K at 20 + Zn at 5 kg, and N at 60 kg + P at 30 kg + S at 20 kg ha^{-1}produced the highest growth rate.

Khatkar *et al.* (2009) performed a field experiment during 2004-2005 at Agricultural Research Farm, Allahabad. The experiment consisted of three factors namely nitrogen (80 and 100 kg ha^{-1}) and sulphur (10, 20 and 30 kg ha^{-1}), phosphorus (40 and 60 kg ha^{-1}) with blanket application of potash at 40 kg ha^{-1}. Highest plant height, SPAD values and maximum plant dry weight was recorded with higher doses of these factors.

Athokpam (2010) conducted a field trial 2003-04 and 2004-05 to study the effect of NPK levels on the growth of broad leaf mustard on clay soil taking 13 treatment combinations consisting of three doses of nitrogen (50, 100 and 150 kg), two levels of phosphorus (50 and 100 kg), two levels of potassium (50 and 100 kg ha^{-1}) and a control for each treatment, replicated thrice. The result revealed that the, leaf area index, net assimilation rate, plant growth efficiency, dry matter percentage increased significantly in highest fertility levels(100 kg N ha^{-1}, 100 kg, P_2O_5 ha^{-1}, and 100 kg K_2O ha^{-1}) in comparison to control.

2.4.2 Effect of fertility levels on yield attributes and yield

Bohra *et al.* (1999) conducted a field experiment to determine the effect of different levels of NPK (25, 50, 75 and 100% of the recommended dose), applied two weeks prior to sowing on Indian mustard cv. Pusa Bold in Varanasi, Uttar Pradesh, India, during 1999-2000 and 2000-01. Significant improvement in crop yield and yield attributes (siliquae $plant^{-1}$, test weight, siliqua length and seed yield $plant^{-1}$) was observed with increasing NPK levels from 25 to 100% of recommended dose.

Singh *et al.* (2000) studied the effect of different levels of N and P and K on Indian mustard cv. Varuna and found that increasing levels of N up to 120 kg ha^{-1}, k and P up to 45 kg ha^{-1} increased the length of siliqua, number of siliqua, seed $siliqua^{-1}$, seed yield and test weight significantly.

Tomar *et al.* (2005) conducted a field experiment in Madhya Pradesh, during the *rabi* season of 2003-04 to investigate the response of Indian **mustard** cultivars (CS-614-4-1-4, SAL-7, Kranti, SAL-9 and CS-52) to **N, P,** K at 60-30-15, 80-40-20, 100-50-25 and 120-60-30 kg/ha. SAL-9 showed higher yields than the other cultivars. Increasing **N, P,** K rates up to 100, 50, 25 produced higher seed, stover and biological yield over rest of the treatments.

Singh and Butter (2006) studied the effect of varying fertility levels on mustard varieties (YTN-6,BSO-772, Vardan, JGN 01-15, Kranti and RH 9801) and found significantly higher yield with 100% RDF compared to 75 of recommended dose.

Ghimire and Bana (2009) conducted an experiment during *rabi* of 2008-09 and 2009-10 at Pantnagar, to study the effect of different doses of recommended fertilizers on yield and yield attributes. They concluded the fact that with an increase in recommended dose of fertilizer (RDF), seed and stover yields increased significantly up to 100% (1.04t/ha and 3.41 t/ha) and 125% of RDF (2.03 t/ha and 6.0 t/ha) in 2008-09 and 2009-10, respectively.

Athokpam (2010) concluded that NPK content and vegetable yield increased significantly with the application of the treatment combination of 100 kg N ha^{-1}, 100 kg, P_2O_5 ha^{-1}, and 100 kg K_2O ha^{-1} in comparison to control in mustard crop.

Paliwal and Singh (2014) conducted a field experiment to evaluate the response of mustard (*Brassica juncea* L. Czernj. and Cosson) to potassium in combination with other nutrients on yield. The results revealed that higher seed yield per hectare was obtained at 150% NPK due to higher values of yield attributing characters viz. number of siliquae per plant, length of siliqua, 1000- seed weight and seed weight per plant.

2.4.3 Effect of fertility levels on nutrient content and uptake

Dixit and Gautam (1996) stated that total uptake of N, P, K were highest in mustard crop receiving the recommended dose of fertilizer i.e. 80-40-40 kg N, P_2O_5, K_2O ha^{-1}. Roy *et al.* (1985) reported that NPK uptake was significantly enhanced with increasing fertility levels from 20, 20, 10 kg N, P_2O_5, K_2O ha^{-1} to 100, 50, 50 kg N, P_2O_5, K_2O ha^{-1}.

Bohra *et al.* (2006) conducted an experiment during the *rabi* season of 1997-98 at Varanasi, to study the growth and nutrient uptake patterns of Indian mustard (*Brassica juncea*) at various levels of N, P and S. Results showed that the uptake of NPK and S by both seed and stover significantly increased with successive increase in nitrogen levels up to 120 kg N ha^{-1}, sulphur levels up to 60 kg S ha^{-1}, and phosphorus levels up to 60 kg P ha^{-1}.

Tomar *et al.* (2005) conducted a field experiment at Madhya Pradesh, during the *rabi* season of 2003-04 to investigate the response of Indian mustard cultivars to different fertility levels. Increasing N, P, K rates up to 100, 50, 25 produced higher N, P and K uptake in comparison to other lower fertility levels

2.4.4 Effect of fertility levels on quality parameters of mustard

Puri *et al.* (1999) while working on effect of fertility levels on mustard quality, found significant influence of varying degrees of fertility levels on soil status of nutrient concentration (N and P) and oil content in seeds (*Brassica juncea*). The highest seed yield and oil content were noted in the treatment 100, 40, 20 kg **N, P,** K ha^{-1}.

Singh *et al.* (2008) studied the effect of fertility level on nutrient uptake of Indian mustard under late sown condition during *rabi* season of 2007 and 2008. The results revealed that oil content increased significantly with increasing fertility level up to 100% RDF (F_2) and thereafter decreased with increase in fertility. However, protein content increased with increasing in fertility level and recorded the highest value at 150% RDF (F_4).

Ghimire and Bana (2009) while working on the effect of fertility levels on quality of mustard at Pantanagar concluded that Oil content decreased but oil yield (340 and 627 kg/ha) and protein content (23.7 and 22.9%) improved significantly up to 100% of RDF in both the years. Similarly, protein yields (245 and 456 kg/ha) and glucosinolate content (80.3 and 87.6 mM/g of seed) increases up to 100 and 125% of RDF in 2008-09 and 2009-10, respectively.

2.4.5 Effect of fertility levels on economics of mustard cultivation

Chaudhary *et al.* (2003) investigated the effect of N, P and Zn on the growth, yield attributes and economics of Indian mustard at Kanpur, Uttar Pradesh. They observed that the application of N at 30 kg + P at 20 kg +K 20 kg + Zn at 5 kg, and N at 60 kg + P at 30 kg +30 kg K + S at 20 kg ha^{-1} produced the highest net return and benefit: cost ratio.

Kumar *et al.* (2006)While working on sandy loam soils of Kukumseri in Lahaul valley of Himachal Pradesh showed that application of 20 kg N, 60 kg P_2O_5 and 30 kg K_2O/ha resulted in highest net return (Rs. 1,40,849) and B:C ratio value of 6.25.

At Pantnagar, Uttarakhand, Ghimire and Bana (2012) working on mustard, to study the effect of different fertility levels on Indian mustard. They concluded the fact that with an increase in recommended dose of fertilizer (RDF), seed and stover yields increased significantly up to 100% (1.04 t/ha and 3.41 t/ha) and 125% of RDF (2.03 t/ha and 6.0 t/ha) in 2008-09 and 2009-10, respectively, thereby increased the net returns to farmers.

2.5 EFFECT OF INTEGRATED NUTRIENT MANAGEMENT

2.5.1 Effect of INM on growth attributes of mustard

The main reason for low productivity of oilseeds in India is inadequate use of nutrients and indiscriminate use of inorganic fertilizers that causes imbalance in soil fertility arising from it. This needs immediate restoration and sustenance of soil fertility through an integration of different available nutrient sources that will increase yield per unit area to meet the shortage of oilseeds.

On clayey soil with pH 7.8 at Nagpur (Maharashtra), Gudadhe *et al.* (2005) observed that the seed inoculation with *Azotobacte*r or/and PSB along with 100% RDF (40, 20, 20 NPK kg ha^{-1}) significantly increased plant height, number of branches, dry matter and leaf area $plant^{-1}$ of mustard (cv. 'Pusa bold'). The inoculation of *Azotobacter* + PSB along with 100% RDF recorded the highest growth rate followed by 75% RDF + *Azotobacter* + PSB.

Mandal and Sinha (2002) while working with effect of INM on growth attributes and yield of Indian mustard concluded that, the plant height, branches plant^{-1}, no of functional leaves per plant and plant dry matter of Indian mustard were improved at 100% recommended rate of NPK + 10 t FYM ha^{-1} compared with 100% NPK alone.

Tripathi *et al.* (2011) conducted a field experiment during *Rabi* season, 2005-06 and 2006-07 at the Crop Research Centre of Pant University of Agriculture and Technology, Pantnagar to study the effect of integrated nutrient management (INM) on growth attributes of Indian mustard cultivar *Kranti.* Application of 100 % recommended dose of fertilizers along with farmyard manure, sulphur, zinc, boron and *Azotobacter* (seed treatment) resulted in maximum plant height, dry matter accumulation, total branches plant^{-1}.

2.5.2 Effect of INM on yield attributes and yield

Sarkar *et al.* (1997) reported that application of high dose of nutrients (80 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1}) half through organic and remaining half through inorganic fertilizers caused 12.17% and 99.5% increase in grain yield respectively as compared to the high dose of nutrients through inorganic fertilizer and crop receiving no fertilizer.

The application of 100% recommended fertility level and 75% of the recommended fertility levels with FYM @ 10 t ha^{-1} were statistically at par in all yield attributes, i.e., number of branches plant^{-1}, number of siliqua plant^{-1} , number of seeds siliqua^{-1} , test weight and seed yield (Jain and Sharma, 2000).

Shrivastva *et al.* (2000) observed that application of 80, 40, 20 kg NPK ha^{-1} and seed inoculation of *Azotobacter* increased the seed yield significantly over sole NPK treatments.

In a field experiment Ghosh *et al.* (2001) while studying the response of 3 levels each of K (0, 12.5, 25 Kg ha-^{1}) and N (0, 40 and 80 kg ha-^{1}) and bio-fertilizers (*Azotobacter*, *Azospirillum*) of rapeseed under irrigated condition. The crop responded significantly to K and N application. Seed inoculation with either of the bacteria significantly improves the yield attributes and yield of seeds and oil, though the magnitude of increase was 23 more with *Azotobacter*. Interaction between K and bio-fertilizer and between bio-fertilizer and N were found significant in increasing the yield of rapeseed.

In another field experiment Mandal and Sinha (2002) studied the yield attributes and yield of Indian mustard (B. juncea) as influenced by different integrated nutrient management treatments (50 and 100% recommended rate of fertilizers (80.0, 17.2, 33.2 kg N, P, K ha^{-1}), 10 t farmyard manure (FYM)ha^{-1}, 10 kg borax ha^{-1} and 20 kg ZnSO4 ha^{-1}. It was at par with 100% NPK + borax + ZnSO4 and 50% NPK + FYM + borax + ZnSO4. Treatment with 100% NPK + FYM, 100% NPK + borax + ZnSO4 and 50% NPK + FYM + borax + ZnSO4 recorded 27, 26 and 25% seed yield increase, respectively, over 100% NPK; and by 134, 132 and 130% over the control.

Chand and Ram (2007) observed that the highest seed yield, stover yield under the treatment 10 t ha^{-1} FYM + 75% of recommended NPK treatment + inoculation with *B. megaterium* var. *phosphaticum* + *Azotobacter chroococcum*. NPK at 75% recommended dose + *Azotobacter chroococcum* increased mustard seed yield by 23% over the control during a field study in Rajasthan, India.

Nagdiv *et al.* (2007) observed that application of 75% RDF + *Azotobacter* + PSB gave highest yield contributing characters and seed yield ha^{-1} of Indian mustard.

Tripathi *et al.* (2011) Pantnagar conducted an experiment to study the effect of integrated nutrient management (INM) on yield of Indian mustard cultivar *Kranti.* concluded that application of 100 % recommended dose of fertilizers along with farmyard manure, sulphur, zinc, boron and *Azotobacter* (seed treatment) resulted in maximum siliquae $plant^{-1}$, seeds $siliqua^{-1}$, test weight and significantly higher seed yield was obtained.

2.5.3 Effect of INM on nutrient content and uptake

Singh *et al.* (2006) carried out a field experiment during 2001-02 and 2002-03, in Rajasthan, to evaluate the response of Indian mustard cv. 'RH-30' to FYM (2.5 and 5 t/ha) and inorganic N (0, 40, 80 kg/ha) applied alone or in combination with biofertilizers (*Azotobacter chroococcum* and *Azospirillum*). Nutrient content and nutrient uptake by plants significantly increased with the application of FYM + biofertilizers (*Azotobactor chroococcum* + *Azospirillum*) over the control.

Field experiment was conducted by De *et al.* (2014) in West Bengal during 2007, 2008 and 2009 to study the effect of integrated nutrient management on nutrient content and uptake and of Rapeseed. He concluded that treatment T (50% RDF + FYM @ 2.5 t ha^{-1} + VC @1.25 t ha^{-1} + NC @ 1.25 t ha^{-1} + PM @ 1.25 t ha^{-1}) recorded highest nutrient uptake with respect to 100 % NPK alone.

2.5.4 Effect of INM on quality parameters of mustard

Abraham and Lal (2002) reported that that 33 per cent recommended dose of NPK along with PSB + *Azospirrilum* + poultry manure significantly increased the oil content and protein content in seed in comparison to NPK levels alone.

Singh and Singh (2006) reported the response of Indian mustard cv. Rh-30 to FYM (2.5 and 5 t ha^{-1}) and inorganic N (0, 40, 80 kg ha^{-1}) applied alone or in combination with bio-fertilizers (*Azotobacter chroococcum*, *Azospirillum*). Seed oil content and oil yield increased significantly with the application of FYM 5 t ha^{-1} along with *Azotobacter chroococcum* and *Azospirillum*.

2.5.5 Effect of INM on economics of mustard production

Under conditions of fertilizer scarcity and escalating cost, economical use of fertilizers and their efficient management is of great significant.

Tripathi *et al.* (2011) conducted a field experiment during *Rabi* season, 2005-06 and 2006-07 at the Crop Research Centre of G. B. Pant University of Agriculture and Technology, Pantnagar to study the effect of integrated nutrient management (INM) on growth, yield and quality of Indian mustard cultivar Kranti. Net returns and B : C ratio were recorded maximum in 100 % recommended dose of fertilizers + 2 t FYM + 40 kg S + 25 kg Zn S04 + 1 kg B ha^{-1} + *Azotobacter* (seed treatment).

A field experiment was conducted by De *et al.* (2014) in the experimental farm of Uttar Banga Krishi Viswavidyalaya, West Bengal during 2007, 2008 and 2009 to study the effect of integrated nutrient management on economics of Rapeseed (Brassica campestris var. yellow sarson). Treatment T (50% RDF + FYM @ 2.5 t ha^{-1} + VC @1.25 t ha^{-1} + NC @ 1.25 t ha^{-1} + PM @ 1.25 t ha^{-1}) recorded highest grain yield of 13.48 q ha^{-1} which was statistically at par with T (T + Neemcake @ 2.5 t ha^{-1}) and T (T +Vermicompost @ 2.5 t ha^{-1}) (13.40 q ha^{-1}). However, T (100 % RDF+ Borax @ 10.0 Kg ha^{-1}) fetched highest B: C ratio.

2.6 EFFECT OF COW URINE:

2.6.1 Effect of cow urine on growth and yield attributes:

Rates of application of nitrogen (N), potassium (K), and sulphur (S) in urine are very high and these can have a marked effect on growth and element concentration of pasture (During & McNaught, 1961; Joblin & Keogh 1979).

Urine causes a marked depression in N fixation by clovers particularly in winter. Distribution data of Richards & Wolton (1976) show that under intensive dairy farming (three cows per ha) urine affects about 40% of the grazed area. Such an addition must cause an overall decrease in N fixation by at least 10% annually.

Ledgard, *et al.* (1982) in New Zealand, evaluated the effects of cow urine and equivalent nitrogen, potassium, and sulphur treatments on pasture yield, botanical composition, herbage chemical composition and N fixation by clovers during winter and spring. They noticed that urine caused a large increase in ryegrass yield, entirely due to Its N content. The effect on yield lasted 2 to 3 harvests. Urine increased the N concentration of grass (particularly the nitrate fraction) and increased the potassium concentration of grass and clover.

Saunders (1987) studied the effects of cow urine and equivalent nitrogen, potassium, and sulphur treatments on pasture yield, botanical composition, herbage chemical composition, and N fixation by clovers were examined during winter and spring. Urine caused a large increase in ryegrass Yield, due entirely to its N component. The effect on yield lasted 2-3 harvests and was followed by a decrease in clover growth. Urine increased the N concentration of grass (particularly the nitrate fraction) and increased the potassium concentration of grass and clover. N fixation by clover was markedly decreased by urine, particularly during the winter.

Leterme *et al.*(2003) used cow urine to study the fate of N applied as urine in spring, summer and autumn on ryegrass receiving two different fertilizer rates (100 and 300 kg N ha^{-1} yr^{-1}) in France. Ammonia volatilization of labeled urine N was less than 4% and immobilized urine N represented 21–31% of the applied 15 N. Recovery of labeled N in plants ranged from 30 to 65% of N input as urine, showing a decrease in autumn for the highest fertilizer nitrogen treatment. The plant recovery of urine N was relatively high in autumn (49%) when urine was deposited on ryegrass receiving a fertilizer rate of 100 kg N ha^{-1} yr^{-1}. Lower N fertilizer regimes can therefore lower the leaching potential of urine N in pastures.

De and Licinio (2007) conducted experiment, at the UFV campus, in a protected environment and organic culture system. The application ways of cow urine (soil and leaf) were allocated in the parcels and the concentrations of cow urine solutions (0.00, 0.25, 0.50, 0.75, 1.00, and 1.25%) were allocated in the sub parcels. Weekly, starting after seven days of seedling transplant, 5, 5, 10, 20 and 20 ml of solution per plant were applied. Cultivar utilized was Regina 2000. When applied via soil, urine concentrations provided significant response in almost all growth attributing characters, with the exception of leaf area; when applied via leaves, there was no effect on the number of leaves, leaf area, stems dry mass, root fresh mass and head volume. The linear increment of SPAD index was observed with applied urine concentration, as well as quadratic response along time. The highest head productivity was registered in plants that received urine solution via leaves in a concentration of 1.25%, corresponding to the increase of 28.1% in productivity, compared to control; when applied via soil, at the optimal concentration of 1.01%, productivity was of 14.92 Mg ha^{-1}, corresponding to the increase of 47.3% in productivity, compared to control. The effects observed on lettuce growth and productivity, due to applied urine solution is due to factors other than only quantity of nutrients used in the solutions.

Oliveira *et al.* (2009) in Zimbawe studied the effect of cow urine on the growth and yield of 'Regina 2000' lettuce, in an experiment carried out from January 13, 2006 to March 22, 2006. Cow urine was applied at different concentrations (0.00, 0.25, 0.50, 0.75, 1.00 and 1.25 %). At harvest, the following variables were evaluated: fresh (FLM) and dry (DLM) leaf mass, fresh (FSM) and dry (DSM) stem mass, stem length (SL), fresh (FRM) and dry (DRM) root mass, fresh (FHM) and dry (DHM) head mass and commercial yield (CY). The increase in cow urine concentrations increased the performance of all lettuce characteristics, except DRM, which presented reduction, and DSM and FRM, which were not affected. The highest yield was obtained with the concentration of 1.25% applied to leaves and with 1.01%, applied to soil, corresponding, respectively to increases of 28.1% and 47.3%, in comparison to the control. Application to leaves, in comparison to application to soil, resulted in greater FLM (0.50 and 1.25%), SL (0.50; 0.75 and 1.25%), FSM and FRM (0.5%), FHM and CY (0.50 and 1.25%), but lower DSM and FRM (1.25%) and DRM (1.0 and 1.25%). The application of cow urine solution at 1.25% to leaves or 1.0% to soil was recommended for lettuce crops.

Vahanka *et al*. (2010) concluded that after regular use of cow urine in the crops farmers of vadodara found that soil microorganism population increased along with the crop yield. It has also improved the soil texture and structure and there was no occurrence of any insect pest and diseases .They concluded that cow urine worked as growth promoters. (Vahanka *et al*. 2010).

Khanal *et al.* (2010) carried out a field experiment in Nepal on farmer's field during 2009-2010, to test the efficacy of cattle urine alone and in combination with urea as a potential supplement to nitrogenous fertilizers in improving yield and quality of cauliflower cv. Kathmandu Local. The experiment was laid out in a randomized complete block design with eight treatments; 100 kg N ha^{-1} supplied by urea, 100 kg N ha^{-1} supplied by urine, 125 kg N ha^{-1} supplied by urine, 75 kg N ha^{-1} supplied by urine, 50 kg N ha^{-1} supplied by urine, 100 kg N ha^{-1} supplied by urea (75 kg) and urine (25 kg), 100 kg N ha^{-1} supplied by urea (50 kg) and urine (50kg), 100 kg N ha^{-1} supplied by urea (25 kg) and urine (75 kg) having three replications. Application of 125 kg N ha^{-1} through urine significantly increased vegetative characters. Application of 100 kg N ha^{-1} through urine significantly increased yield and quality characters as compared to application of either higher or lower dose of urine. Fifty percent substitution of urea by urine produced better morphological, yield and quality character than other combinations of urine and urea.

Singh *et al*. in 2012 concluded that, 15 tonnes FYM + 120, 60, 30 kg N, P_2O_5, K_2O/ha and spray of fresh cow urine and *Neemuchmutka khad* improved soil health along with sustainable productivity of rice under temperate condition. Thus the application of 15 tonnes FYM + 120, 60, 30 kg N, P_2O_5, K_2O/ha along with three spray of Neemuch mutka khad or fresh cow urine in rice was found suitable.

Singh *et al*. (2014) conducted a field experiment to assess the effect of varied levels of nitrogen and cow urine on rice crop during *kharif* season of 2009 with the six treatment combinations as T_1 = NPK (120, 60, 60 kg ha^{-1}), T_2 = NPK (120, 60, 60 kg ha^{-1} +cow urine), T_3 = NPK (100, 60, 60 kg ha^{-1} + cow urine),T_4 = NPK (90, 60, 60 kg ha^{-1} + cow urine) and T_5 = NPK (60, 60,60 kg ha^{-1} cow urine) including control (T_0). The application of nitrogen @ 90 kg ha^{-1} with 60 kg ha^{-1}potassium and phosphorus + cow urine (T_4) was found to be the best treatment regarding growth, yield and nitrogen content of paddy.

Cow's urine boosted the annual rye grass yield by causing an increase in nitrogen (N) content of the soil but a marked depression in N fixation by 10% annually in clovers particularly in winter. The effects on yield lasted 2-3 harvests and were followed by a decrease in clover growth. Total N content in the cow urine is very high ranging from 6.8 to 21.6 g N/l, out of which an average of 69% is urea. Urine increased the N concentration of grass (particularly the nitrate fraction) and increased the potassium concentration of grass and clover. Increased pasture growth from urine patches has been observed even following high N fertilizer application which may be due to greater amount of N applied or to some interaction with one of the other elements in urine such as potassium or sulphur (Mohanty *et al.* 2014).

Timothy *et al*. (2014) carried out an in vitro assay at Zimbabwe, to establish if cow urine at different concentrations (500 µL/ml, 300 µL/ml, 200 µL/mL, and 100 µL/mL) can be used to control the growth of *F. lateritium*, the fungal agent causing *Fusarium* bark disease in coffee. The undiluted cow urine was most effective in inhibiting fungal growth with the rest of the cow urine concentrations showing dose dependent efficacy compared to the negative control ($P < 0.01$).

2.6.2 Effect of cow urine on economics:

Gupta and Yadav (2001) conducted field trials in *kharif* season for evaluating cow urine efficacy against stem borers and cost benefit in soybean production. There was reduction in percent stem tunneling at almost all levels of cow urine. The yield data indicates that cow urine at 25, 50 and 75 % concentration recorded significantly higher yield than control. Highest cost benefit ratio (1: 18.9) was obtained from 75% cow urine.

Khanal *et al.* (2010) carried out a field experiment in Nepal on farmer's field during 2009-2010, to test the efficacy of cattle urine alone and in combination with urea as a potential supplement to nitrogenous fertilizers in improving yield and quality of cauliflower cv. Kathmandu Local. The highest curd yield and the highest benefit cost ratio (5.84) were observed by application of 100 kg N ha^{-1} through urine.

Chapter III

MATERIALS AND METHODS

A field experiment entitled **"Effect of fertility levels and cow application on growth, yield and quality of Indian mustard [*Brassica juncea* (L.) Czernj. & Cosson]"** was conducted during winter (*rabi*) season of 2013-14 at the IFS block of Agricultural Research Farm, Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh (India), situated under North East Plain Zone of the country. The detailed information on location, soil, climatic and weather condition recorded during the crop season along with materials used and methods employed are described in this chapter.

3.1 LOCATION OF THE EXPERIMENTAL SITE

The Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University is situated at a distance of 10 kilometer from Varanasi railway station in the south east direction. The geographical situation of the farm lies in the Northern Gangetic Alluvial plain at 25°18' North latitudes, 83°03' East longitude and at an altitude of 80.71 meters above the mean sea level.

The experimental field was well drained with uniform topography and assured source of water supply.

3.2 CLIMATIC CONDITION OF VARANASI

The weather of Varanasi has been classified under moisture deficit zone-4 with moisture deficit index of -20 to -40 per cent and falls in the belt of semi arid to sub humid climate having hot summer and cold winter. The normal period for the onset of monsoon in this region is the third week of June and it lasts up to the end of September and sometimes up to first week of October. A light shower of rain is often experienced in January and February. Months of March to May are generally dry. The average annual precipitation (P) of Varanasi is 1100 mm and annual potential evapotranspiration (PET) is about 1525 mm. So the annual moisture deficit in this region is 425 mm. The distribution of rainfall as percentage of annual is 88% from June to September, 5.7% from October to December, 3.3% from January to February and 3% from March to May. The differences between total rainfall received (about

875 mm) and evaporation losses (about 665 mm) are always positive (about 210 mm) during rainy season (from July-October). However, in the subsequent months from November onwards to June, the differences are always negative. Varanasi comes under semi humid climate with extremely hot weather in May-June and cold during winter. Generally maximum and minimum temperature ranges between 23^0C to 40^0C and from 4.9^0C to 24.5^0C, respectively. The temperature begins to rise from the middle of February and reaches to its maximum in May and middle of June. The coldest period of the year is between last weeks of December to first week of January. The mean relative humidity is 70 per cent, which rises up to 82.8 per cent during July to September and fall down to 35 per cent during the end of April to early June. Data on meteorological parameters were recorded at the meteorological observatory of the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, during the period of experimentation, have been described below

3.2.1 Temperature (°C)

The weekly mean maximum and minimum temperature during the experimentation ranged from 31.9 °C to 17.5°C and 9.8 to 20.1 °C, respectively. The maximum temperature was recorded 31.9 °C in the 12^{th} standard week (March) whereas; the lowest minimum temperature remained 9.8 °C in the month of January.

3.2.2 Rainfall (mm)

The total rainfall received during the crop period (Nov.5 to March 25) was 134.4 mm. The pattern of rainfall distribution was not normal during the experimental period. The highest rainfall (37.1 mm) was recorded during the meteorological week No.3^{rd} of 2014.

3.2.3 Relative humidity (%)

The weekly maximum relative humidity ranged between 66 to 94 per cent and minimum relative humidity varied from 38 to 76 per cent during the period of experimentation i.e. 46^{th} to 11^{th} standard week

Table 3.1: Meteorological observations during the crop growing period (2013-14)

Week No.	Month & Date	Rainfall mm	Temperature (^{0}C)		R.H. (%)		Wind Speed (km hr^{-1})	Sunshine hours	Evaporation (mm)
			Max	Min	Max.	Min.			
45	Nov 05-11	0.0	27.7	15.5	84	60	0.6	7.6	1.6
46	12-18	0.0	26.2	11.5	90	48	1.2	7.9	1.5
47	19-25	0.0	26.7	25.0	89	41	1.0	8.5	1.8
48	26-02	0.0	26.4	13.7	87	46	1.9	8.1	1.6
49	Dec 03-09	0.0	25.4	13.7	89	43	1.3	8.2	1.5
50	10-16	0.0	24.0	10.6	88	48	2.5	8.3	1.7
51	17-23	0.0	23.5	11.5	83	57	2.0	7.5	1.6
52	24-31	0.0	21.1	10.3	85	49	3.1	7.8	1.4
1	2014, Jan 1-7	0.0	20.7	11.3	91	59	3.1	6.9	1.3
2	8-14	22.4	17.9	10.7	92	68	3.2	2.0	1.1
3	15-21	37.1	18.1	10.6	92	76	2.1	0.6	0.8
4	22-28	0.0	20.4	11.7	94	63	3.2	2.4	1.4
5	29-04	0.0	20.1	9.8	89	63	1.9	4.6	1.2
6	Feb 05-11	0.0	24.9	12.3	81	45	3.2	9.1	2.7
7	12-18	24.4	20.4	11.0	83	54	3.8	3.1	1.3
8	19-25	15.5	23.5	12.3	82	64	1.8	7.6	1.8
9	26-04	34.5	23.9	15.6	87	68	2.9	3.6	1.8
10	March 05-11	0.0	27.0	13.0	83	45	2.3	8.1	3.0
11	12-18	0.5	28.5	15.9	82	55	2.5	8.3	3.5
12	19-25	0.0	31.9	17.5	66	38	2.6	9.5	4.7

3.2.4 Sunshine duration (hrs)

The average duration of bright sunshine was 6.49 hours. The maximum and minimum weekly bright sunshine duration ranged between 0.6 and 9.5 hours, respectively during the period of investigation.

3.2.5 Evaporation (mm)

The evaporation data obtained from weather bureau class A Pan Evaporimeter revealed that the average evaporation during the crop period varied from 0.8 to 4.7 mm day^{-1}.

3.3 FIELD EXPERIMENT

A field experiment was conducted on mustard during winter season of 2013-14 at the Agriculture research farm, Institute of Agricultural Sciences, B.H.U., Varanasi, U.P.

3.4 SOIL OF EXPERIMENTAL SITE

Table 3.2: Chemical properties of Initial soil sample

Parameters	Value	Method employed
Organic carbon (%)	0.38	Walkley and Black's (Jackson,1973)
*p*H (1:2.5 Soil : water suspension)	7.8	Glass electrode digital *p*H meter (Jackson, 1973)
Electrical conductivity (1:2.0 Soil : water suspension) (dS m^{-1}) at 25^0C	0.18	Systronics electrical conductivity meter (Jackson, 1973)
Available N (kg ha^{-1})	138.48	Alkaline permanganate method (Subbiah and Asija,1956)
Available P_2O_5 (kg ha^{-1})	23.48	0.5 *N* $NaHCO_3$ extractable (Olsen *et al*., 1954)
Available K_2O (kg ha^{-1})	172.10	Ammonium acetate extractable flame photometer (Jackson,1973)
Available S (mg kg^{-1})	20.73	Turbidity method
Available B (mg kg^{-1})	0.75	Hot water extract
Available Zn (mg kg^{-1})	0.53	EDTA extract

3.5 CROPPING HISTORY OF EXPERIMENTAL FIELD

Field experiment was conducted at the IFS block of Agricultural Research Farm, Institute of Agricultural Sciences during rabi 2013-14 at fixed site to study, the Effect of fertility levels and cow urine on growth, yield and quality of Indian mustard [*Brassica juncea* (L.) *Czernj*. & *Cosson*.].

Table 3.3 Cropping History

Year	*Kharif*	*Rabi*
2008-09	Rice	Wheat
2009-10	Rice	Wheat
2010-11	Rice	Wheat
2011-12	Rice	Wheat
2012-13	Rice	Wheat
2013-14	Rice	Present experimental crop(Mustard)

3.6 EXPERIMENTAL DETAILS

The experiment was laid out in split plot design with three replications. The main plot treatment consisted three fertility levels i.e. 50%, 75% and 100% RDF (Recommended fertilizers dose)where as four levels of cow urine i.e. 0, 300, 600, 900 l ha^{-1} were allocated to sub-plots. So the total numbers of treatment combinations were twelve. The treatments were replicated thrice to avoid any effect of heterogeneity. The treatments within main plots and sub-plots were randomly allocated in each replication as per standard procedure. The details of treatments are given in table 3.6.2 and layout plan in fig 3.2.

3.6.1 Details of layout

Main plot treatments	3
Sub-plot treatments	4
No. of Treatment combinations	12
No. of replications	3
Total no. of plots	36
Experimental design	Split plot
Gross plot size	7.2 m × 2.68 m
Net plot size	6.4 m × 1.65 m
Field border	1.5 m
Plot border	0.75 m
Replication border	1.0 m
Main irrigation channel	1 m
Sub irrigation channel	1.0 m

- Main plot treatment – Three fertility levels

  F1= 50% (Recommended Dose of Fertilizer)

  F2=75% (Recommended Dose of Fertilizer)

  F3=100% (Recommended Dose of Fertilizer)

- Subplots treatment –Four levels of cow urine application(U)

  U0= 0 l. Urine + 900 l. Water/ha

  U1= 300 l Urine + 600 l. Water/ha

  U2= 600 l Urine + 300 l. Water/ha

  U3= 900 l Urine + 0 l. Water/ha

3.6.2 Chemical analysis of cow urine used in the experiment

N (%)	K (%)	P (%)	Ca (%)	Mg (%)	S (%)	P^H
0.976	1.1	0.0917	0.01	0.1	0.081	7.97

3.6.3 Treatment combinations

Symbol	Treatments
F_1U_0	50% RDF*+ 0 l. Urine + 900 l. Water/ha
F_1U_1	50% RDF + 300 l. Urine + 600 l. Water/ha
F_1U_2	50% RDF + 600 l. Urine + 300 l. Water/ha
F_1U_3	50% RDF+ 900 l. Urine + 0 l. Water/ha
F_2U_0	75% RDF + control U0 + 900 l. Water/ha
F_2U_1	75% RDF + 300 l. Urine + 600 l. Water/ha
F_2U_2	75% RDF + 600 l. Urine + 300 l. Water/ha
F_2U_3	75% RDF + 900 l. Urine + 0 l. Water/ha
F_3U_0	100% RDF + control U0 + 900 l. Water/ha
F_3U_1	100% RDF + 300 l. Urine + 600l. Water/ha
F_3U_2	100% RDF + 600 l. Urine + 300 l. Water/ha
F_3U_3	100% RDF + 900 l. Urine + 0 l. Water/ha

*RDF: 120 kg N + 60 kg P_2O_5 + 60 kg K_20 + 40 kg S ha^{-1}

3.7 SELECTION OF EXPERIMENTAL MATERIALS

3.7.1 Source of nutrients

3.7.1.1 Inorganic sources

Urea

Urea is most widely used N fertilizer and is produced by heating ammonia with CO_2 under high temperature (160 - 170°C). Urea contains the highest percentage of nitrogen (46.6%) among solid fertilizers. It contains nitrogen in the amide form. This organic fertilizer is cheaper than any other solid nitrogenous fertilizer in India.

Di-ammonium phosphate (DAP)

Di-ammonium phosphate is the most commonly used phosphatic fertilizer and is produced by reacting calcium nitrate with mono-calcium phosphate and it contains 18% N and 46% P_2O_5.

Muriate of potash (MOP)

Muriate of potash or potassium chloride (KCl) is most common and cheapest fertilizer among the potassic fertilizers. It contains 58-60% K_2O.

Elemental sulphur

Sulphur is applied in the form of elemental sulphur. Elemental sulphur contains 80% S.

3.7.1.2 Organic sources

Cow Urine

Fresh cow urine was collected from the IFS unit of Agricultural Research Farm of the Institute of Agricultural Sciences, B.H.U. Jersey and Holstein-Friesian cross bred cows maintained in the dairy unit of IFS model were given balanced diet consisting of dry fodder, green fodder, concentrate, salt, mineral mixture and calcium. Storage of urine was done in plastic container at room temperature. The urea N content of the urine was determined 1 day before application to ascertain the amount of nutrients applied.

3.8 CROP AND VARIETY

Crop	:	Mustard
Botanical name	:	*Brassica juncea* (L.) *Czernj. & Cosson*.
Family	:	Brassicaceae
Variety	:	Pro agro 4001

Pro agro 4001

The cultivar 'Pro agro 4001' is mostly suited for the regions of Rajasthan, Haryana, Gujarat, Uttar Pradesh and Bihar. The seed is the dark brown and the plants take 120-140 days to mature. It is medium to tall in height ranging from 1.6 to 1.85 m. The yield potential of this cultivar is 12 to 20 q ha^{-1} having bold seeds with 38-40% oil.

3.9 FIELD OPERATIONS

The details of the field operations performed during the period of experimentation are described in Table 3.6.

Table 3.6: Schedule of cultural operations

S. No.	Operations	Date
1.	Ploughing and planking	06.10.2013
2.	Layout of the experimental field	11.11.2013
3.	Sowing	12.11.2013
4.	Fertilizers application	11.11.2013
5.	Thinning	30.11.2013
6.	Weed management	
	a. Pre emergence application of Pendimethalin @3 l./ha	13.11.2013
	b. Hand rotary weeding	10.12.2013
7.	Spraying of insecticide (Rogor)	07.01.2014
8.	Spraying of fungicide(Dithane M. 45)	28.01.2014
9.	Irrigation	23.01.2014 15.02.2014
10.	Harvesting	28.03.2014
11.	Threshing	1.04.2014

3.9.1 Land preparation

Proper field preparation and fine seed bed are essential for good germination and growth of mustard in order to have a suitable field for sowing. The experimental field was ploughed criss- cross with a tractor drawn disc and dry weeds as well as stubbles were removed. The field was again ploughed by cultivator and finally planking was done to obtain a good tilth. The block borders and plot bunds were made manually as per the layout plan (Fig. 3.1). The experimental plots were leveled before sowing of seeds.

3.9.2 Nutrient application

Furrows were opened in each plot at a distance of 40 cm. Half of N and full doses of phosphorus and potassium as per treatment were applied in furrows after mixing with moist soils The sources of nitrogen, phosphorus, potassium and sulphur were Urea, DAP, MOP and elemental sulphur, respectively. The rest half nitrogen was top dressed through urea at one month stage. Cow urine with or without water as per treatment was also applied in furrows through rose can. Cow urine was applied in the soil as per the treatment just before sowing.

3.9.3 Seed rate and sowing

After the final field preparation, the seeds of 'Pro agro 4001' Indian mustard were sown at the rate of 5 kg ha^{-1} at a row distance of 40 cm. The sowing was done in furrrows, opened with the help of *kudal* and covered after sowing.

3.9.4 Thinning

Thinning of plants was done after 18 days of sowing in order to keep only one robust and healthy plant at a distance of 15 cm to maintain proper plant population. Each plot accommodated 18 rows.

3.9.5 Water management

The crop was grown under irrigated condition. One pre sown and two post sowing irrigation were applied to save the crop and maintain optimum soil moisture for plant growth.

3.9.6 Weed management

Pendimethalin was applied as pre emergence spray. This was accompanied by one mechanical-cum-mannual weeding at 4 week stage of the crop.

3.9.7 Plant protection

To protect crop from aphids (*Lipaphis erysimi*) Dimethoate 30EC was sprayed @1.0 l. /ha during flowering to pod formation stages. As a prophylactic measure against alternaria blight mancozeb @ 2.5 kg ha^{-1} was also mixed with the spray solution for aphid.

3.9.8 Harvesting and threshing

The crop was harvested as soon as 80 per cent siliquae turn yellowish brown to prevent shattering. First of all border plants were harvested. Thereafter, plants from each net plot area were harvested carefully, bundled, tagged and were taken to threshing floor and kept separately. After proper sun drying the bundles were threshed separately.

3.10 OBSERVATIONS RECORDED

For recording biometric observation at regular interval, two sampling area i.e. one for destructive and other for non- destructive were marked. The observations like plant height and branches were taken from non-destructive sampling area i.e. net plot area while the observation like dry matter accumulation per plant were taken from destructive area i.e. area apart from net plot. For recording growth parameter of 5 plants from net plot area were selected randomly and tagged and their observation were recorded at 30, 60, 90 DAS and at harvest. Yield and yield attributing character were recorded after harvest.

3.10.1 Plant height (cm)

Plant height of five randomly tagged plants was measured from base of plant up to the growing tips of main stem and average height was recorded in cm.

3.10.2 Functional leaves plant^{-1}

The number of functional green leaves per plant were counted and expressed as average number of leaf per plant.

3.10.3 Leaf Area Index (LAI)

Leaves of five plants taken from each penultimate rows as treatment wise for dry matter observation were removed for leaf area estimation which was recorded with a leaf area meter (Systronics 211). The LAI was worked out using the formula as suggested by Radford (1967).

$$\text{Leaf Area Index} = \frac{\text{Leaf area / plant (cm}^2\text{)}}{\text{Land area / plant (cm}^2\text{)}}$$

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

For recording dry matter accumulation, 5 plants from each plot were cut from the ground level of border rows. 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}.

3.10.5 Branches plant^{-1}

Five randomly tagged plants were used for counting the number of branches. All primary and secondary branches were counted at 30, 60, 90 DAS and at harvest. The average number of branches per plant was worked out.

3.10.6 Siliquae on main shoot

Total numbers of siliquae on main shoot of five tagged plants were counted and average number of siliquae on main shoot was computed. Total number of siliquae on five tagged plant were counted and average number of siliquae per plant was recorded.

3.10.7 Siliqua length (cm)

Length of 10 siliqua of each five plants was measured with a linear scale and expressed as mean length of siliqua (cm).

3.10.8 Seeds siliqua^{-1}

Ten siliquae of each five plants used for measuring siliqua length were split open and number of seed was counted and the mean was expressed.

3.10.9 Test weight (1000-seed weight)

From the representative sample of each plot one thousand seeds were counted and weighed to record 1000 seeds weight in gram.

3.10.10 Seed yield (kg ha^{-1})

The seed yield of net plot after cleaning and proper drying was recorded in grams and converted into kilogram per hectare by multiplying with appropriate conversion factor.

3.10.11 Stover yield (kg ha^{-1})

After threshing stem and chaff weight per plot were recorded and added treatment-wise. These were converted to kilogram per ha by multiplying with appropriate conversion factor.

3.10.12 Harvest index (%)

Harvest index was calculated by the formula given below by Donald and Hamblin, 1978:

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Bilogical yield}} \times 100$$

Where,

Economic yield = seed yield (kg ha^{-1})

Biological yield = seed yield + stover yield (kg ha^{-1})

3.11 LABORATORY STUDIES

3.11.1 Oil content in seed

Oil content in seed was estimated by Soxhlet method given by Sankaran (1966).

$$\text{Oil content (\%)} = \frac{\text{Weight of oil (g)}}{\text{Weight of seed sample (g)}} \times 100$$

3.11.2 Oil yield (kg ha^{-1})

Oil yield was obtained from oil content multiplied by seed yield and expressed in kg per hectare.

$$\text{Oil yield (kg ha}^{-1}\text{)} = \frac{\text{Oil content (\%) in seed} \times \text{seed yield (kg ha}^{-1}\text{)}}{100}$$

3.11.3 N, P and K content in plant

Plant material for this study was drawn at harvest of mustard and the seed were dried at 70˚C for 48 hours, the plant material thus obtained was ground with the help of grinder and passed through mesh sieve and then used for determination of N, P and K contents. The nutrient content of were then estimation as following method give in Table 3.7.

Table 3.7: Chemical analyses of plant

Analysis	Method	Reference
Total 'N'	Micro Kjeldahl method	Jackson (1973)
Total 'P'	Vanadomolybdate phosphoric acid yellow colour method	Jackson (1973)
Total 'K'	Flame photometer method	Jackson (1973)

3.11.4 Estimation of nitrogen in stover and seed sample

Nitrogen content in plant and seed sample was determined by Modified Kjeldahl Method as per procedure outlined by Gupta (2007). In a digestion tube 0.5 g of powdered plant straw was taken and 10 ml of di-acid solution (9:1, H_2SO_4:$HClO_4$) was added and kept for overnight then 10g of sulphate mixture [(20 parts K_2SO_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. 10 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 0.005 N H_2SO_4. Blank was also run and N content was calculated by formula.

Calculation

$$\text{Percent N in Plant material} = \frac{T \times 0.005 \times 0.014 \times 50 \times 100}{10 \times 0.5}$$

T = Sample reading - Blank reading

3.11.5 Digestion for P, K in stover and seed

0.5 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 HNO_3: $HClO_4$) was added to it and was kept overnight. It was then digested on a block digester till a colorless 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. Digestion of seed was also done in similar manner.

3.11.6 Phosphorus content in stover and seed

Five 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 (drop wise) till it become colorless. 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 stover and seed was calculated using standard curve and expressed as total P (%). Same procedure was followed to determination of P content in seed. Standard solution of 1, 2,3,4,5 and 10 ppm were prepared.

Calculation

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

3.11.7 For Potassium content in stover and seed

Potassium content of plant and seed 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 as under.

Calculatio*n*

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

Where, R = Flame photometer reading, Dilution factor = 50/0.5 = 100 times

3.12 RELATIVE ECONOMICS

The economics of various treatments was worked out separately by taking into account the existing price of inputs and produce. The investment on fertilizers, labour, and power for performing different operations such as ploughing, weeding, irrigation, harvesting, threshing etc. were worked out (` $ha^{-1}$) as per rate prevalent at the Agricultural Research Farm, Institute of Agricultural Sciences, B.H.U., Varanasi. The cost of cultivation was taken into account for calculating economics of treatments and expressed as net return (` ha^{-1}) and output: input ratio.

(a) Gross income (` ha^{-1})

The yield of rice crop was converted into gross income in ` per hectare on the basis of current price of the grain and straw.

(b) Net return (` ha^{-1})

The net return was worked out by using following formula:

Net return (`Rs. $ha^{-1}$) = Gross income (`Rs. ha^{-1}) – cost of cultivation (`Rs. ha^{-1})

(c) Benefit: cost ratio (B: C ratio)

The output: input ratio was worked out on the basis of net return per unit cost of cultivation (Rs. ha^{-1}).

$$\textbf{Benefit : cost ratio} = \frac{\text{Gross income (`Rs. ha}^{-1}\text{)}}{\text{Cost of cultivation (`Rs. ha}^{-1}\text{)}}$$

3.13 STATISTICAL ANALYSIS

The observations recorded during the course of investigation were tabulated and analyzed statistically to draw a valid conclusion. The data were analyzed as per the standard procedure for "Analysis of Variance" (ANOVA) as described by Gomez and Gomez (1984). The significance of treatments was tested by 'F' test (Variance ratio). Standard error of mean was computed in all cases. The difference in the treatment mean were tested by using Critical Difference (CD) at 5% level of probability where 'F' test showed significant differences among means by the following formula:

$$CD = \sqrt{\frac{2 \times error\ sum\ of\ square}{N}} \times t\ (error\ d.f.\ 5\%)$$

The results have been presented in the tabular form and depicted in figure wherever necessary.

Fig. 3.1. Standard Week wise metrological Observations recorded at Metrological Observatory, B.H.U. during the period of experimentation (2013-2014)

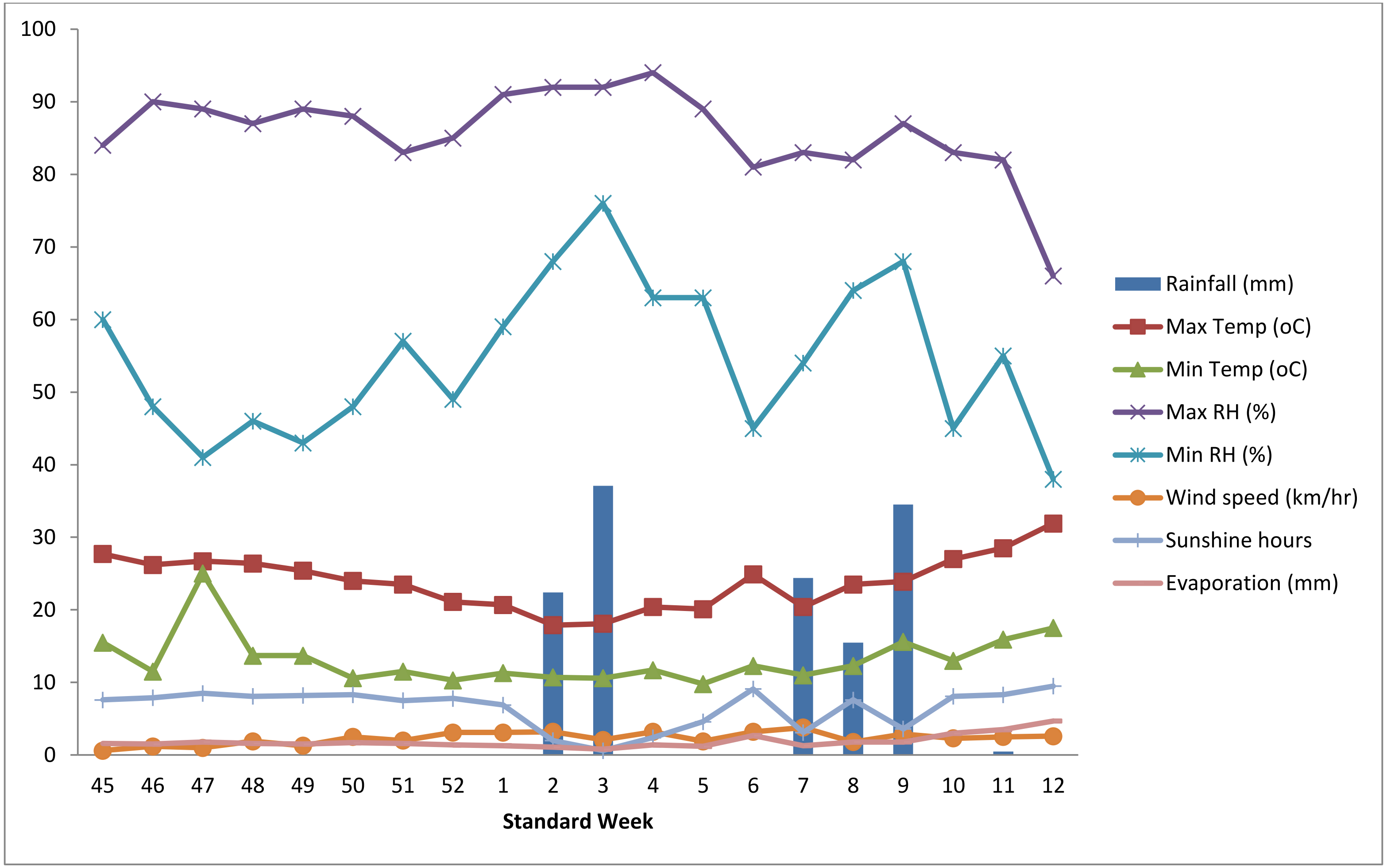
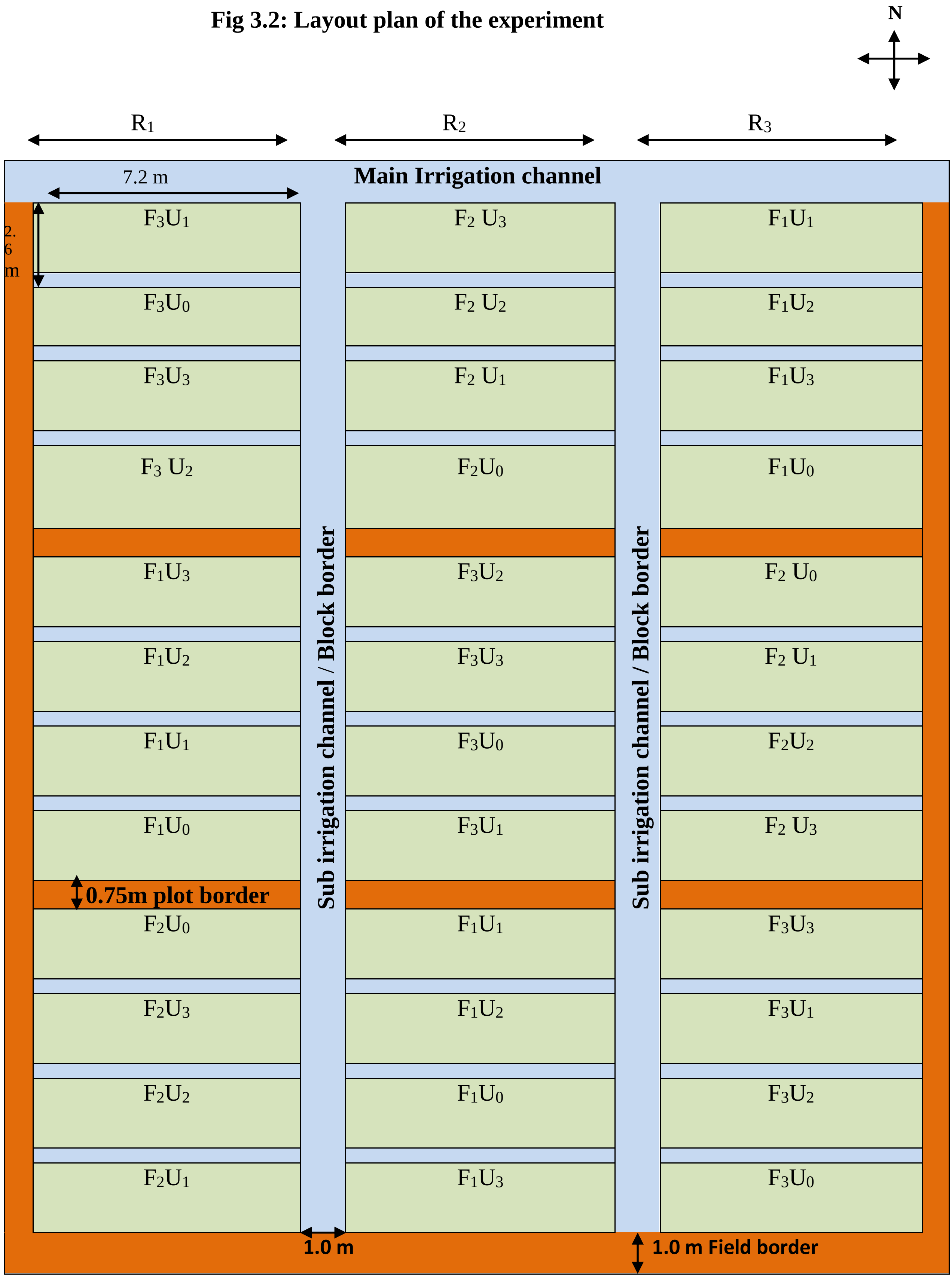


Fig 3.2: Layout plan of the experiment



Chapter IV

EXPERIMENTAL FINDINGS

The summary of the experimental findings recorded during the course of study are presented in this chapter. Data recorded during the course of experiment were statistically analyzed and significant variation thus obtained, are described hereunder. As none of the interactions was found significant only the main effects have been presented.

4.1. EFFECT OF TREATMENTS ON GROWTH PARAMETERS

4.1.1. Plant height

The data pertaining to plant height at different stages of crop growth as influenced by various treatments are presented in Table 4.1. A critical scanning of the data revealed that different fertility levels caused marked variation on plant height at all stages. It also observed that the plant height increased rapidly with advancement of phenophases of crop up to 90 DAS, thereafter the linear growth was almost seized.

Increasing levels of fertility from 50 to 100 % caused marked improvement in plant height at all the growth stages. However, 50 % and 75 % RDF at 30 DAS and 60 DAS and 75% and 100 % RDF at 90 DAS and at harvest remained statistically at par.

Variation in plant height due to urine levels was also observed at all stages of plant growth. Lucid improvement in plant height was noticed with increasing levels of urine application of 600 and 900 l ha^{-1}. Nevertheless, at most of the stages significant variation was observed only between 0 and 600 as well as o and 900 l urine l ha^{-1}.

4.1.2 Number of functional leaves $plant^{-1}$

Data on number of functional leaves $plant^{-1}$ as influenced by different fertility levels and urine levels are summarized in Table 4.2. Critical study of data showed that green leaves $plant^{-1}$ increased from 30 to 60 DAS and thereafter it declined. Scrutiny of the data shows that cow urine and fertility levels significantly influenced the number of functional leaf $plant^{-1}$ at all the dates of observation. Increasing levels of fertility from 50 to 100 % RDF resulted in corresponding increase in number of green leaves plant^{-1} which was significantly higher than lower fertility levels at all stages of observation. However, it was also noted that at 50 and 75 % RDF remained statistically at par with respect to number of functional leaves per plant.

Increase in levels of urine application showed marked improvement on production of functional leaves plant^{-1} at all the stages of observation. Application of 600 and 900 l urine ha^{-1} though remained comparable produced significantly higher number of functional leaves plant^{-1} than control at the stages of observation.

4.1.3 Leaf Area Index (LAI)

Observations recorded on LAI of mustard at 60 days after sowing are presented in Table 4.3.

It is evident from data that there was a marked improvement in LAI with each increment in fertility levels from 50 to 100 % RDF. Application of 75 % and 100 % RDF though remained at par, produced significantly higher LAI than 50% RDF.

Urine application also showed lucid effect on LAI of mustard. Increasing levels of urine application from 0 to 900 l ha^{-1} correspondingly increased the LAI at 60 DAS. However, the differences between 300 and 600 as well as 600 and 900 l ha^{-1} correspondingly increased the LAI at 60 DAS. However, the differences between 300 and 600 as well as 600 and 900 l ha^{-1} of urine application failed to touch the level of significance.

4.1.4 Chlorophyll content (SPAD values)

Chlorophyll in terms of SPAD was recorded in top 3 fully opened leaves at 60 and 90 DAS. The relevant of the data on chlorophyll content as affected by different treatments are presented in Table 4.3. Perusal of the data revealed that with every increment in fertility levels there was increase in chlorophyll content of crop at both the stages. At 60 DAS, 75% and 100% RDF did not differ significantly with respect to SPAD value.

Data presented in table 4.4 further revealed marked effect of urine application on chlorophyll content of the test crop at 30 as well as 60 DAS. Increasing levels of urine application from 0 to 900 l ha^{-1} correspondingly improved the SPAD values. 600 and 900 l urine ha^{-1} though remained at par, produced significantly higher chlorophyll content than 300 l urine ha^{-1} and control.

4.1.5 Number of primary branches plant^{-1}

Data on primary branches plant^{-1} as influenced by different fertility levels and cow urine are presented in Table 4.4. A cursory glance over the data revealed marked improvement on the production of primary branches plant^{-1} at successive growth stages up to harvest. It may further be noted that there was significant difference in number of primary branches plant^{-1} with increasing fertility levels from 50 to 100 % RDF at all the growth stages.

Increasing levels of urine from 0 to 900 l ha^{-1} showed increasing trend, in terms of number of primary branch plant^{-1} at all the stages of observation. Application of 600 and 900 l. cow urine ha^{-1} though remained comparable recorded significantly higher number of primary branch plant^{-1} at 60 and 90 DAS as well as harvest.

4.1.6 Number of Secondary branches plant^{-1}

Data on Secondary branches plant^{-1} as influenced by fertility levels and urine levels has been presented in Table 4.5.

Perusal of the data revealed lucid effect of fertility levels enhanced number of secondary branches plant^{-1}. Secondary branches plant^{-1} declined significantly with decreasing soil fertility from 100 to 50 % RDF. Nevertheless, at 30 DAS, the difference between 0 and 300 l urine ha-^{1} did not turn significant with respect to secondary branches plant^{-1}.

Urine application also influenced the production of secondary branch in test crop. Progressive increase in the number of secondary branches plant^{-1} was noticed with each increment of urine level up to highest level at all the stages of observation. Application of 600 and 900 l urine ha^{-1} produced significantly higher number of secondary branches plant^{-1} than control. However, the difference between 300 and 600 l urine ha^{-1} was also significant at 60 and 90 DAS as well as at harvest.

4.1.7 Dry matter production (g plant^{-1})

The data on dry matter production in crop plant as influenced by different fertility and cow urine levels are presented in Table 4.6.

It is evident from the data that dry matter production plant^{-1} increased as growth progressed, the values being maximum at harvest. Increasing levels of fertility correspondingly enhanced dry matter accumulation up to the highest level. With every increment of fertility levels up to 100 % RDF, there was a sharp increase in dry matter accumulation at all the stages. However, at 60 DAS, difference between 75 % and 100% failed to touch the level of significance.

Dry matter accumulation plant^{-1} was found to improve with urine application. Increasing levels of urine application from 0 to 900 l ha^{-1} enhanced dry matter accumulation at all the stages. At 30, 90 DAS and at harvest application of 600 and 900 l urine ha^{-1} produced significantly higher dry matter plant^{-1} than lower level.

4.2 YIELD AND YIELD ATTRIBUTES

The data pertaining to yield attributes of tested crop are presented in Table 4.7. Fertility levels and urine levels significantly influenced the yield contributing characters of mustard.

4.2.1 Number of siliqua on main shoot

Data on number of siliqua on main shoot as influenced by various treatments are summarized in Table 4.7. A close examination of the data revealed marked reduction in number of siliqua on main shoot with decreasing fertility levels from 100 to 50% RDF and the differences were significant between any two fertility levels

It may further be noted that urine application of 300 l, 600 l, 900 l, produced marked increase with respect to number of siliqua on main shoot over the control. Notwithstanding the difference, between control and 300 l urine ha^{-1} remained comparable.

4.2.2 Number of siliqua plant^{-1}

Data on number of siliqua plant^{-1} as affected by fertility levels and urine levels are given in Table 4.7.

Scanning of the data revealed that significant effect of different fertility levels on number of siliqua plant^{-1}. Increasing levels of fertility from 50 to 100 percent RDF progressively increased number of siliquae plant^{-1}. However, the difference between 75 and 100 % RDF did not turn significant.

Application of cow urine also influenced the siliquae production in mustard. It was noted that increase in urine levels from 0 to 900 l ha^{-1} urine correspondingly enhanced the number of siliqua per plant and the urine applied at 300, 600 and 900 l urine ha^{-1} produced significantly higher siliquae $plant^{-1}$ then control. Similarly, 900 l urine ha^{-1} also proved its distinct superiority over 300 l urine ha^{-1}.

4.2.3 Length of siliqua (cm)

Data pertaining to length of siliqua are given in Table 4.7. Siliqua length was found to increase with increasing fertility levels from 50 to 100 % RDF. Nevertheless, the significant difference was noticed only between 50 and 100 % RDF.

Perusal of the data in Table 4.7 further revealed that increasing levels of urine application, though increased siliqua length of mustard but the differences did not differ significantly.

4.2.4 Seeds $siliqua^{-1}$

Data presented in Table 4.8 revealed pronounced effect of fertility levels on seeds $siliqua^{-1}$. Decreasing fertility levels from 100 to 50 % RDF significantly reduced the number of seeds/ siliqua.

Marked effect of urine application was also noticed on the production of seeds/siliqua. Increasing levels of urine application from 0 to 900 l urine ha^{-1} correspondingly increased the number of seeds $siliqua^{-1}$. Nevertheless, the differences could touch the level of significance only between 0 and 600 as well as 0 and 900 l urine ha^{-1}.

4.2.5 Test weight (1000 seed weight)

Data on fertility levels and urine levels imparted significant variation in 1000-seed weight (g) of mustard depicted in Table 4.8. It is evident from the data that fertility levels differed markedly in respect of test weight of 1000 seeds. Test weight increased with increasing fertility levels from lowest to highest fertility levels. Among the fertility levels 100 % RDF recorded highest test weight of (4.76 g), followed by 75 per cent (4.40 g) and 50 per cent (3.97 g). However, the difference 75 to 100 % RDF failed to touch the level of significance.

As regards the urine application, test weight of mustard improved markedly with increasing levels of urine application from 0 to 900 l urine ha^{-1}. However, the difference between 0 and 300 l ha^{-1} and 600 and 900 l ha^{-1} were not significant.

4.2.5 Seed yield (kg ha^{-1})

The Data pertaining to seed yield (kg ha^{-1}) of mustard influenced by different treatments are given in Table 4.9.

The data revealed that there was significant increase in seed yield with increasing fertility levels. Application of 100 % RDF produced 12.1 and 31.2 % higher seed yield than 75 % and 50 % RDF respectively.

It is also cleared from the data that with increasing levels of urine application, the seed yield (kg ha^{-1}) of mustard improved markedly with increase in urine levels up to 600 l ha^{-1} over the control. However the difference between 600 and 900 l ha^{-1} urine could not touch the level of significance.

4.2.6 Stover yield (kg ha^{-1})

The Data pertaining to stover yield (kg ha^{-1}) of mustard influenced by fertility and cow urine levels are given in Table 4.9.

It is apparent from the data that stover yield (kg ha^{-1}) was influenced due to fertility levels. With increase in fertility levels there was a steady improvement in the stover yield (kg ha^{-1}) up to highest level i.e. 900 l ha^{-1}. Nevertheless, the significant difference was noticed only between the 50 and 100 % RDF.

A cursory glance over the data revealed marked improvement in stover yield with the application of urine. The data suggested that there was lucid improvement in straw yield with each increment in urine levels from lowest to highest. However, 300 l urine ha^{-1} failed to exert distinct superiority over control.

4.2.6 Harvest index (%)

The data on harvest index (%) as influenced by fertility levels as well as urine levels are given in Table 4.9.

It is evident from the data that increasing fertility levels markedly increased the harvest index but the differences could not reach to the level of significance.

The data presented in table 4.9 further revealed that harvest index of test crop increased between 0 and 300 l urine ha^{-1} and thereafter declined up to highest level i.e. 900 l urine ha^{-1}. Nevertheless, the differences remained comparable.

4.3 QUALITY PARAMETERS

4.3.1 Oil content (%)

The data pertaining to seed oil content of Indian mustard seed are presented in Table 4.10. A close review of data revealed that increasing levels of fertility resulted in corresponding increase in oil content from 50 to 100 %. However, the increase in seed oil content was significant only between 50 to 100 % RDF.

Perusal of the data in Table 4.10 further revealed that increasing levels of urine application though increased the seed oil content (%) of mustard. However the differences could prove significant only between 0 and 600 and 0 and 900 l urine ha^{-1}.

4.3.2 Oil yield (kg ha^{-1})

The cursory glance of data on oil yield (kg ha^{-1}) as influenced by fertility levels and cow urine are presented in Table 4.10 revealed that fertilizer application resulted marked improvement in oil yield that increased significantly with increasing fertility levels. The maximum oil yield of 450 kg ha^{-1} was obtained with highest fertility level that recorded 16.3% and 36.4% higher oil yield than 75 % and 50 % RDF, respectively.

As regards the urine application, oil yield of mustard improved markedly with increasing levels of urine application from 0 to 900 l urine ha-^{1}. However, the oil yield did not differ significantly between 600 and 900 l urine ha^{-1}.

4.3.3 Protein content in seed (%)

The data pertaining to protein content are presented in Table 4.10. Scrutiny of the data revealed marked effect of fertility levels on the protein content of mustard seed. Increasing fertility level from 50 to 100 % RDF correspondingly enhanced the seed protein content. However, the significant improvement in seed protein content was noticed only between 50 and 100 % RDF.

As regards the urine application, protein content of mustard seed improved with increasing levels of urine application from 0 to 900 l urine ha-^{1}. Application of 600 and 900 l urine ha-^{1} though remained comparable recorded significantly higher seed protein content than control.

4.3.4 Protein yield (kg ha^{-1})

The data on protein yield (kg ha^{-1}) as influenced by fertility levels are presented in Table 4.10. It is apparent from the data that fertilizer application influenced seed protein yield. Increasing fertility levels from 50 to 100 % RDF caused significant increase in protein yield. All the fertility level differed significantly in respect of seed protein content.

It is also clear from the data that with regards to urine application, the protein yield (kg ha^{-1}) of mustard improved with increase in urine levels up to 900 l/ha. Application of 600 and 900 l urine ha-^{1} though remained at par recorded significantly higher protein yield than lower level of urine application.

4.4 EFFECT OF FERTILITY AND COW URINE LEVELS ON N, P, K CONTENTS IN SEED AND STOVER

4.4.1 Nitrogen content (%) in seed

Data on seed N contents of mustard as influenced by fertility and cow urine levels are presented in table 4.11. A close examination of the data revealed marked effect of fertility levels on N content of seed. However the differences could touch the level of significance only between lowest and highest fertility levels.

As regards the cow urine application, seed N content increased with increasing levels of urine applications from 0 to 900 l urine ha^{-1}. Nevertheless, the significant difference was established only between 0 and 600 as well as 0 and 900 l urine ha-^{1}.

4.4.2 Phosphorus content (%) in seed

A critical study of data on P content in seed Table 4.11 indicated improvement in seed P content with each increment in fertility level. However the differences could not touch the level of significance.

Similarly, seed P content was also increased with increasing levels of urine application from 0 to 900 l urine ha^{-1} but the differences between any two levels remained comparable.

4.4.3 Potassium content (%) in seed

A critical study of the data presented in table 4.11 revealed that seed K content of the test crop improved with increasing levels of fertility from 50 to 100 %. However, the differences did not differ significantly.

Increasing levels of cow urine application, from 0 to 900 l ha-^{1} increase the seed K content. Nevertheless, the differences remained statistically at par.

4.4.4 Nitrogen content (%) in stover

Data pertaining to N content in stover, summarized in table 4.11 revealed, improvement in N content of stover. Nevertheless, the difference could not touch the level of significance.

Further analysis of data revealed improvement in N content of stover with each increment of urine level up to the highest level (900 l urine ha-^{1}). However, the differences were significant only between 0 and 900 l urine ha-^{1}.

4.4.5 Phosphorus content (%) in stover

Data on P content in stover are presented in table 4.11. An inspection of the data revealed improvement in P content of stover with increasing levels of fertility from 50 t0 100 % RDF. However, the differences were not significant.

Similarly, the different levels of cow urine application failed to influence P content of stover to the level of significance.

4.4.6 Potassium content (%) in stover

Data pertaining to K content in stover furnished in table 4.11 revealed that increasing levels of fertility from 50 to 100 % RDF correspondingly enhanced K content of stover. However, significant difference could not be noticed between any two fertility levels.

Similarly, increasing levels of urine application from 0 to 900 l urine ha-^{1} though improved K content of stover but the differences were not significant.

4.5 EFFECT OF FERTILITY AND COW URINE LEVELS ON N, P AND K UPTAKE

4.5.1 Nitrogen uptake by seed (kg ha^{-1})

An examination of the data presented in table 4.12 showed that there was lucid effect of fertility levels on N uptake by seed. Increasing levels of fertility from 50 to 100 % RDF significantly increased N uptake by seed.

Increasing levels of cow urine application from 0 to 900 l ha-^{1} also enhanced N uptake by seed. However, 600 and 900 l urine ha-^{1} remained comparable.

4.5.2 Phosphorus uptake by seed (kg ha^{-1})

Data on P uptake by seed are presented in table 4.12. Scrutiny of the data revealed marked effect of fertility levels on P uptake by seeds. P uptake by seeds decreased significantly with decreasing levels of soil fertility from 100 to 50 % RDF.

Data presented in table further revealed marked effect of cow urine application on p uptake by seed. Increasing levels of urine application increased P uptake by seed up to highest level. Application of 600 and 900 l urine ha^{-1} recorded significantly higher P uptake by seed than control. Similarly, the difference between 900 and 300 l urine ha^{-1} was also significant.

4.5.3 Potassium uptake by seed (kg ha^{-1})

Perusal of the data presented in table 4.12 indicated lucid effect of fertility levels on K uptake by seed. K uptake by seed increased significantly with each increment of fertility level.

K uptake by seed was also improved with increasing levels of urine application from 0 to 900 l urine ha^{-1}. Application of of 600 and 900 l urine ha^{-1} though remained comparable, recorded significantly higher K uptake by seed than 0 l urine ha^{-1}. The difference between 900 and 300 l urine ha^{-1} was also significant.

4.5.4 Nitrogen uptake by stover (kg ha^{-1})

Perusal of the data regarding N uptake by stover presented in table 4.12 indicated that increasing levels of fertility from 50 to 100 % RDF significantly increased N uptake by stover.

Similarly, increasing levels of cow urine application from 0 to 900 l ha-^{1} increased N uptake by stover. However, 0 and 300 l urine ha-^{1} remained statistically at par.

4.5.5 Phosphorus uptake by stover (kg ha^{-1})

Data on P uptake by stover presented in table 4.12 revealed that increasing levels of fertility from 50 to 100 % RDF correspondingly improved P uptake by stover. However, the differences were significant only between the lowest and highest fertility levels.

Increasing levels of cow urine application from 0 to 900 l urine ha-^{1} also improved P uptake by stover. Application of 600 and 900 l urine ha-^{1} recorded significantly higher P uptake by stover than control. The difference between 900 and 300 l urine ha-^{1} was also significant with respect to P uptake by stover.

4.5.6 Potassium uptake by stover (kg ha^{-1})

Scrutiny of data presented in table 4.12 showed increase in K uptake by stover with increasing levels of fertility from lowest to highest. However, the differences could touch the level of significance only between 50 and 100 % RDF.

K uptake by stover was increased with each increment of urine level up to highest level. Application of 600 and 900 l urine ha-^{1} though remained comparable, recorded significantly higher K uptake by stover than 300 l urine ha^{-1} and control.

4.6 ECONOMICS

The data pertaining to economics of mustard as influenced by various treatments are presented in Table 4.13. An introspection of data revealed that, there was marked difference in the cost of cultivation of mustard under different treatments. The cost of cultivation was markedly enhanced with increasing fertility levels from 50 to 100 % RDF.

Similarly, with each increment of cow urine application there was corresponding increase in cost of cultivation of mustard up to 900 l ha^{-1}.

4.6.1 Gross return

The data with respect to gross return or income as influenced by fertility and cow urine levels are presented in 4.13. An insight into the data clearly demonstrated that gross return enhanced significantly with each increment of fertility level, recording maximum at 100 % RDF.

Lucid effect of cow urine application was also observed on gross return. Application of 600 and 900 l. cow urine ha^{-1} significantly increased gross return over lower levels of urine application.

4.6.2 Net return

Data presented in table 4.13 revealed marked effect of fertilizer application on net return of mustard. Increasing fertility levels from 50 to 100 % RDF correspondingly improved net return. However, the differences could turn significant only between 50 and 100 % RDF.

Net return of mustard was increased with increasing levels of cow urine application up to 900 l ha^{-1}. Application of 900 l cow urine ha^{-1} though remained comparable to 600 l cow urine ha^{-1}, recorded significantly higher net return over control and 300 l cow urine ha^{-1}.

4.6.3 Benefit: Cost ratio (B: C ratio)

Data pertaining to benefit: Cost ratio as affected by various treatments is presented in Table 4.13. A close examination of data revealed improvement in B: C ratio due to increasing levels of fertility from 50 to 100 % RDF. Nevertheless, the differences failed to touch the level of significance.

Further, it was observed that benefit: Cost ratio improved with increasing levels of cow urine application up to 600 l cow urine ha^{-1}, thereafter it declined at highest level of urine application. However, the significant difference in B : C ratio was observed only between 0 and 600 l cow urine ha^{-1}.

Table 4.1 Effect of fertility and cow urine levels on plant height (cm) at different growth stages of mustard

Treatment	Plant height (cm)			
	30 DAS	**60 DAS**	**90 DAS**	**At harvest**
Fertility levels				
50% RDF	16.3	84.2	128.8	139.0
75% RDF	16.0	86.8	136.1	151.1
100% RDF	17.1	90.9	139.8	156.7
S. Em±	0.24	1.12	1.96	1.51
C.D. 5%	0.93	4.39	7.69	5.94
Cow urine levels (l ha^{-1})				
0	15.5	81.8	130.2	143.8
300	16.2	85.0	134.0	147.6
600	16.7	89.6	136.9	150.7
900	17.3	92.9	138.6	153.7
S. Em±	0.24	1.18	1.16	1.68
C.D. 5%	0.72	3.52	3.44	4.98

Table 4.2 Effect of fertility and cow urine levels on number of functional leaf plant^{-1} at different growth stages of mustard

Treatment	Functional leaves plant^{-1}		
	30 DAS	**60 DAS**	**90 DAS**
Fertility levels			
50% RDF	4.83	13.73	12.51
75% RDF	5.17	15.15	13.81
100% RDF	6.83	17.12	15.30
S. Em±	**0.23**	**0.42**	**0.06**
C.D. 5%	**0.92**	**1.66**	**0.25**
Cow urine levels (l ha^{-1})			
0	4.89	14.00	13.10
300	5.60	15.11	13.50
600	5.86	15.87	13.92
900	6.22	16.35	15.00
S. Em±	**0.29**	**0.37**	**0.40**
C.D. 5%	**0.85**	**1.10**	**1.18**

Table 4.3 Effect of fertility and cow urine levels on Chlorophyll content (SPAD) and LAI of mustard

Treatment	Chlorophyll content		LAI
	30 DAS	60 DAS	60 DAS
Fertility levels			
50% RDF	22.1	40.1	3.10
75% RDF	25.5	43.6	3.52
100% RDF	28.4	44.8	3.70
S. Em±	**0.42**	**0.36**	**0.08**
C.D. 5%	**1.66**	**1.41**	**0.32**
Cow urine levels (l ha^{-1})			
0	23.5	41.2	3.10
300	24.6	42.1	3.37
600	26.3	43.6	3.60
900	27.0	44.5	3.69
S. Em±	**0.45**	**0.48**	**0.08**
C.D. 5%	**1.33**	**1.42**	**0.25**

Table 4.4 Effect of fertility and cow urine levels on primary branches plant^{-1} at different growth stages of mustard

Treatment	**Primary branches plant^{-1}**		
	60 DAS	**60 DAS**	**At harvest**
Fertility level			
50% RDF	3.53	5.28	5.28
75% RDF	4.39	5.90	5.90
100% RDF	5.35	6.89	6.89
S. Em±	**0.21**	**0.12**	**0.12**
C.D. 5%	**0.81**	**0.48**	**0.48**
Cow urine level (l ha-^{1})			
0	3.95	5.55	5.55
300	4.30	5.92	5.92
600	4.47	6.16	6.16
900	4.95	6.45	6.45
S. Em±	**0.17**	**0.15**	**0.15**
C.D. 5%	**0.51**	**0.43**	**0.43**

Table 4.5 Effect of fertility and cow urine levels on secondary branches plant^{-1} at different growth stages of mustard

Treatment	Secondary branches plant^{-1}		
	60 DAS	**90 DAS**	**At harvest**
Fertility levels			
50% RDF	3.65	8.21	8.21
75% RDF	4.30	11.03	11.03
100% RDF	5.30	14.26	14.26
S. Em±	**0.22**	**0.37**	**0.37**
C.D. 5%	**0.88**	**1.47**	**1.47**
Cow urine level (l ha^{-1})			
0	3.94	10.27	10.27
300	4.29	10.74	10.74
600	4.47	11.29	11.29
900	4.98	12.37	12.37
S. Em±	**0.17**	**0.32**	**0.32**
C.D. 5%	**0.51**	**0.95**	**0.95**

Table 4.6 Effect of fertility and cow urine levels on shoot dry weight (g plant^{-1}) at different growth stages of mustard

Treatment	Dry matter accumulation (g plant^{-1})			
	30 DAS	**60 DAS**	**90 DAS**	**At harvest**
Fertility level				
50% RDF	1.8	37.0	50.1	56.1
75% RDF	2.6	40.3	62.3	69.4
100% RDF	3.1	44.3	68.3	75.8
S. Em±	**0.05**	**0.90**	**1.26**	**1.37**
C.D. 5%	**0.18**	**3.53**	**4.95**	**5.36**
Cow urine level (l ha^{-1})				
0	2.0	38.9	55.9	60.9
300	2.3	39.8	57.9	65.5
600	2.7	41.2	62.9	70.3
900	3.1	42.8	64.4	71.8
S Em+	**0.11**	**0.76**	**1.40**	**1.38**
C.D. 5%	**0.34**	**2.27**	**4.17**	**4.11**

Table 4.7 Effect of fertility and cow urine levels on yield attributes of mustard

Treatment	Siliquae on main shoot	Siliquae/plant	Siliquae length (cm)
Fertility levels			
50% RDF	37.7	130.3	4.38
75% RDF	42.5	133.7	4.58
100% RDF	48.0	136.7	4.72
S. Em±	**0.57**	**0.75**	**0.06**
C.D. 5%	**2.3**	**2.9**	**0.22**
Cow urine levels (l ha^{-1})			
0	40.5	130.9	4.47
300	41.6	133.3	4.55
600	43.6	134.7	4.56
900	45.2	135.4	4.66
S. Em±	**0.39**	**0.66**	**0.10**
C.D. 5%	**1.2**	**2.0**	**NS**

Table 4.8 Effect of fertility and cow urine levels on yield attributes of mustard

Treatment	Seeds siliqua^{-1}	1000-seed weight (g)
Fertility levels		
50% RDF	6.58	3.78
75% RDF	8.17	4.19
100% RDF	9.50	4.53
S Em±	**0.34**	**0.09**
C.D. 5%	**1.35**	**0.37**
Urine level (l ha^{-1})		
0	7.11	3.97
300	8.00	4.05
600	8.33	4.24
900	8.88	4.40
S Em±	**0.33**	**0.08**
C.D. 5%	**0.97**	**0.23**

Table 4.9 Effect of fertility and cow urine levels on seed yield, stover yield and harvest index (%) of mustard

Treatment	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)
Fertility levels			
50% RDF	930	2709	25.6
75% RDF	1069	2970	26.6
100% RDF	1220	3270	27.4
S. Em±	**34.0**	**111.6**	**0.90**
C.D. 5%	**133**	**438.3**	**NS**
Cow urine levels (l ha^{-1})			
0	996	2710	26.8
300	1052	2803	27.3
600	1115	3091	26.5
900	1130	3327	25.4
S. Em±	**12.7**	**52.0**	**0.43**
C.D. 5%	**37.6**	**155.1**	**1.3**

Table 4.10 Effect of fertility and cow urine levels on quality parameters of mustard

Treatment	Oil content (%)	Oil yield (kg ha^{-1})	Protein content (%)	Protein yield (kg ha^{-1})
Fertility levels				
50% RDF	35.46	330	19.3	179
75% RDF	36.19	387	19.9	213
100% RDF	36.86	450	20.6	251
S Em±	**0.27**	**11.9**	**0.21**	7.0
C.D. 5%	**1.06**	**46.7**	**0.84**	27.3
Cow urine level (l ha^{-1})				
0	35.25	352	19.3	192
300	35.96	379	19.8	209
600	36.69	409	20.1	225
900	36.78	416	20.4	231
S Em±	**0.30**	**6.2**	**0.24**	3.0
C.D. 5%	**0.90**	**18.3**	**0.71**	8.8

Table 4.11 Effect of fertility and cow urine levels on N, P, K content (%) in seed and stover of mustard

Treatment	N (%)		P (%)		K (%)	
	Seed	Stover	Seed	Stover	Seed	Stover
Fertility levels						
50% RDF	3.08	0.73	0.579	0.090	0.72	1.08
75% RDF	3.19	0.75	0.629	0.096	0.77	1.16
100% RDF	3.29	0.82	0.655	0.100	0.78	1.19
S. Em±	0.03	**0.02**	**0.023**	**0.003**	**0.02**	**0.03**
C.D. 5%	**0.13**	**NS**	**NS**	**NS**	**NS**	**NS**
Cow urine levels (l ha^{-1})						
0	3.08	0.721	0.609	0.092	0.72	1.08
300	3.16	0.733	0.621	0.096	0.74	1.14
600	3.22	0.781	0.624	0.097	0.76	1.17
900	3.27	0.797	0.630	0.097	0.81	1.18
S. Em±	**0.04**	**0.021**	**0.020**	**0.003**	**0.03**	**0.04**
C.D. 5%	**0.11**	**0.060**	**NS**	**NS**	**NS**	**0.11**

Table 4.12 Effect of fertility and cow urine levels on N, P and K uptake by seed and stover of mustard

Treatment	N uptake (kg ha^{-1})		P uptake (kg ha^{-1})		K uptake (kg ha^{-1})	
	Seed	Stover	Seed	Stover	Seed	Stover
Fertility levels						
50% RDF	28.63	19.9	5.38	2.44	6.65	29.42
75% RDF	34.12	22.4	6.73	2.84	8.19	34.44
100% RDF	40.15	26.9	7.99	3.30	9.57	39.15
S. Em±	**1.11**	**0.37**	**0.29**	**0.12**	**0.29**	**1.25**
C.D. 5%	**4.37**	**1.47**	**1.14**	**0.49**	**1.15**	**4.91**
Cow urine levels (l ha^{-1})						
0	30.78	19.5	6.12	2.49	7.15	29.27
300	33.43	21.7	6.56	2.70	7.78	32.09
600	35.96	24.2	6.97	3.00	8.49	36.41
900	37.04	26.7	7.15	3.26	9.14	39.43
S. Em±	**0.47**	**0.75**	**0.23**	**0.12**	**0.32**	**1.15**
C.D. 5%	**1.41**	**2.23**	**0.68**	**0.36**	**0.94**	**3.41**

Table 4.13 Effect of fertility and cow urine levels on economics of mustard cultivation

Treatment	Gross return (Rs.) ha^{-1}	Cost of cultivation (Rs.) ha^{-1}	Net return (Rs.) ha^{-1}	B:C ratio
Fertility levels				
50% RDF	39924	25286	14638	1.577
75% RDF	45749	28213	17535	1.621
100% RDF	52078	31156	20922	1.671
S. Em±	**1388**	**-**	**1388**	**0.052**
C.D. 5%	**5449**	**-**	**5499**	**NS**
Cow urine levels (l ha^{-1})				
0	42533	27255	15277	1.555
300	44889	27897	16991	1.608
600	47705	28539	19166	1.669
900	48541	29189	19360	1.660
S. Em±	**504**	**-**	**504**	**0.019**
C.D. 5%	**1497**	**-**	**1497**	**0.055**

Market price of produce (Rs kg^{-1})

Seed : 40

Stover : 1

Fig. 5.1. Effect of fertility and cow urine levels on plant height of mustard

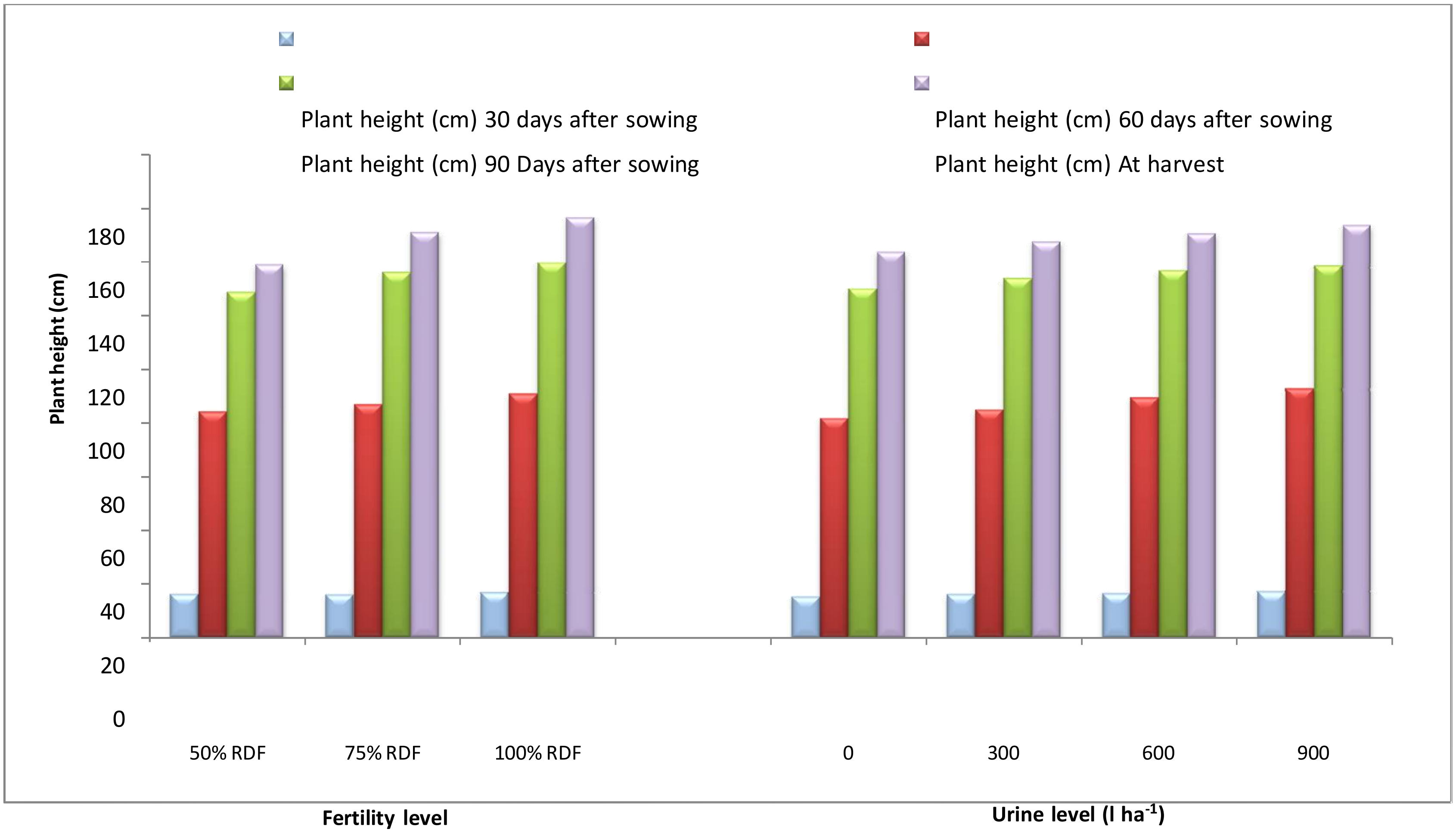


Fig. 5.2. Effect of fertility and cow urine levels on number of primary & Secondary branches/plant of mustard

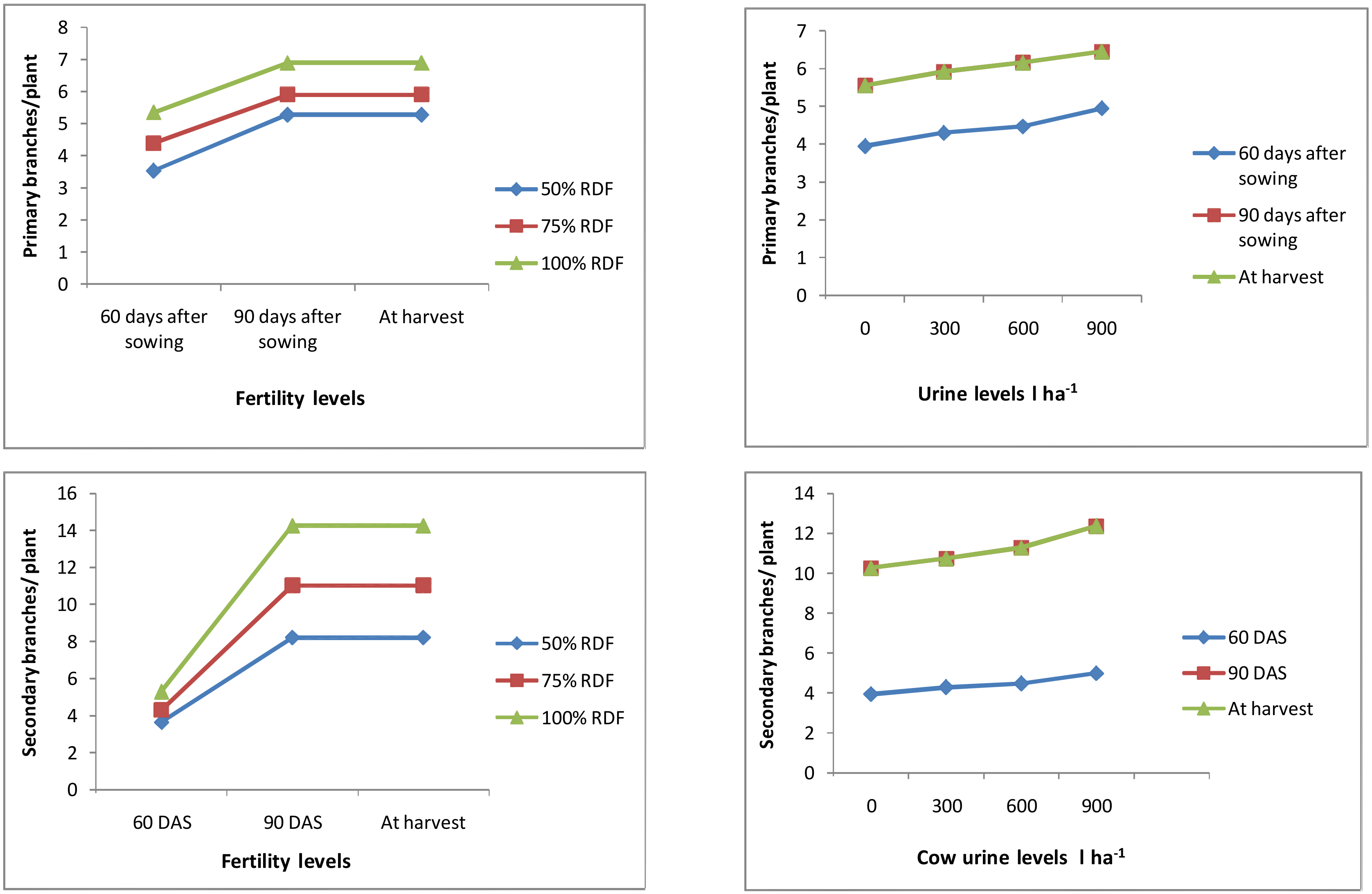
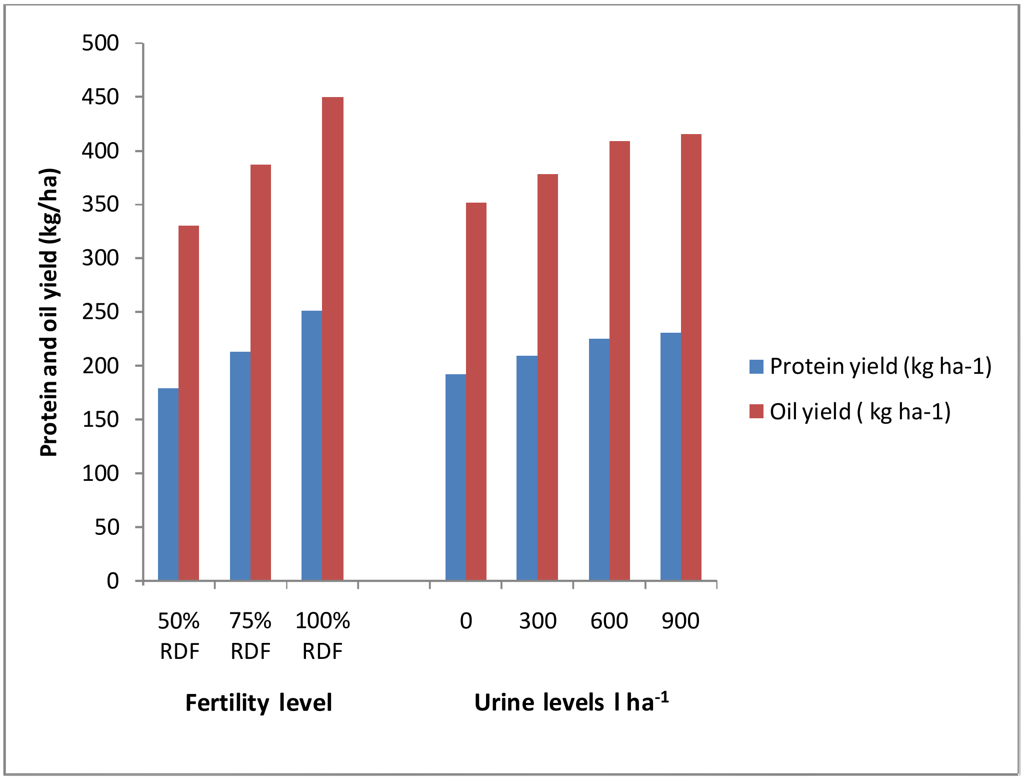


Fig. 5.6. Effect of fertility and cow urine levels on quality Parameters of mustard



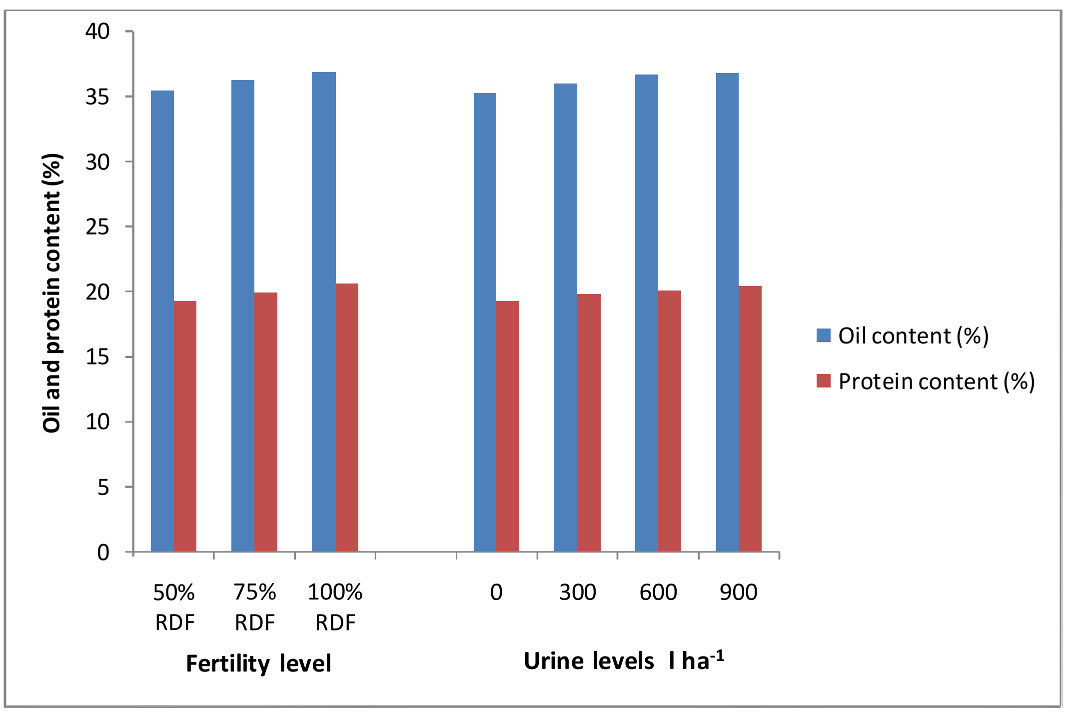
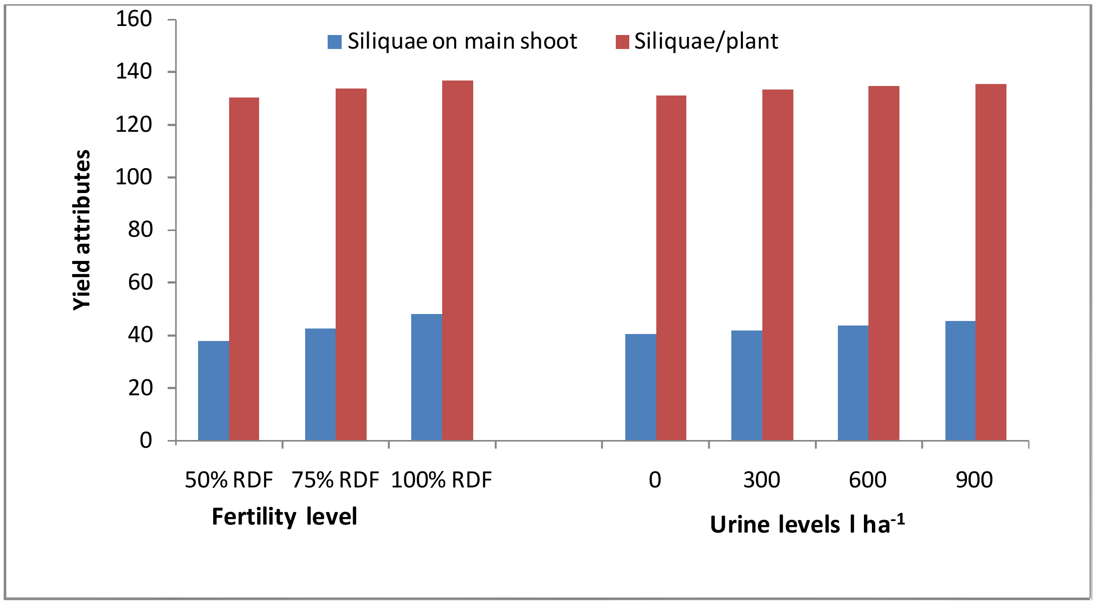


Fig. 5.4. Effect of fertility and cow urine levels on yield attributes of mustard



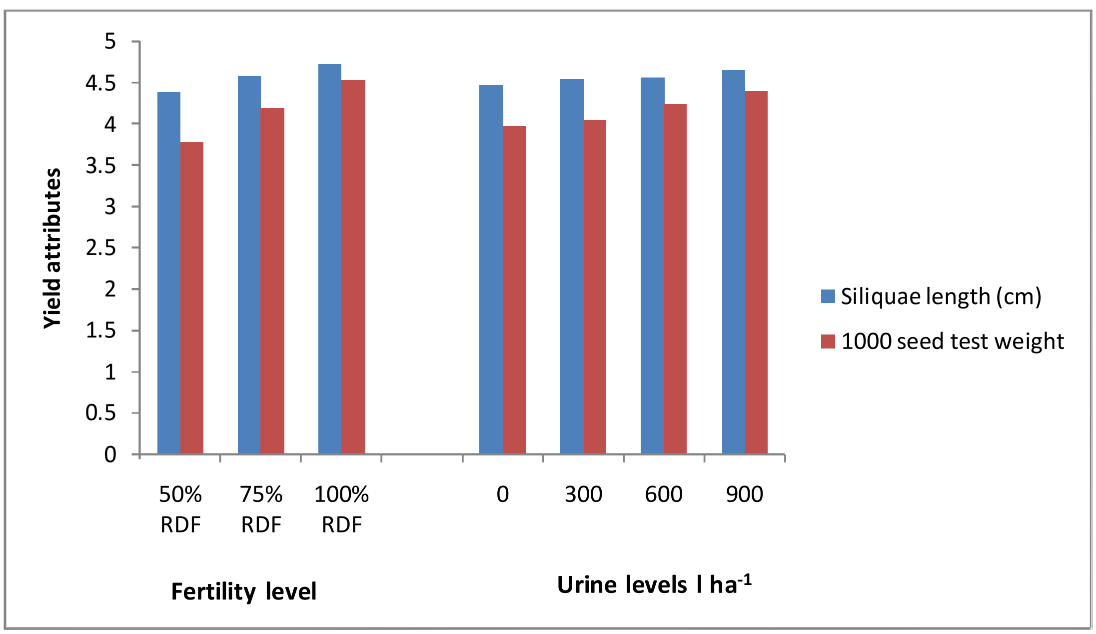
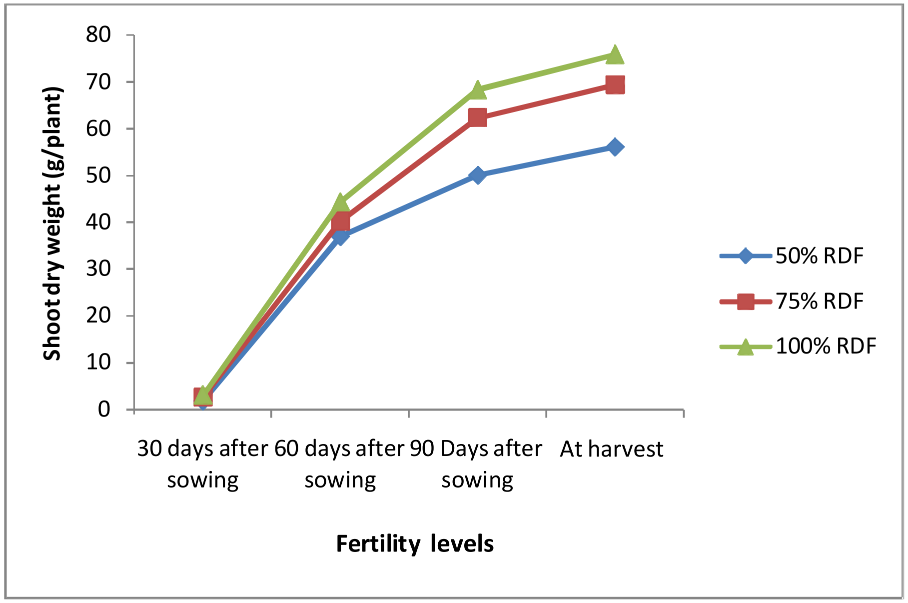


Fig. 5.3. Effect of fertility and cow urine levels on shoot dry weight (g/plant)



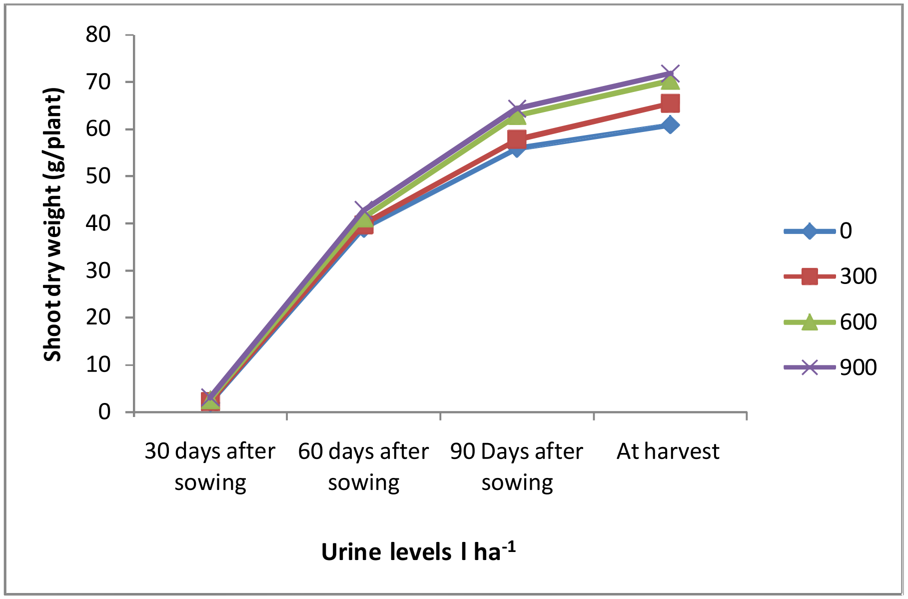


Fig. 5.5. Effect of fertility and cow urine levels on Seed and Stover yield of mustard

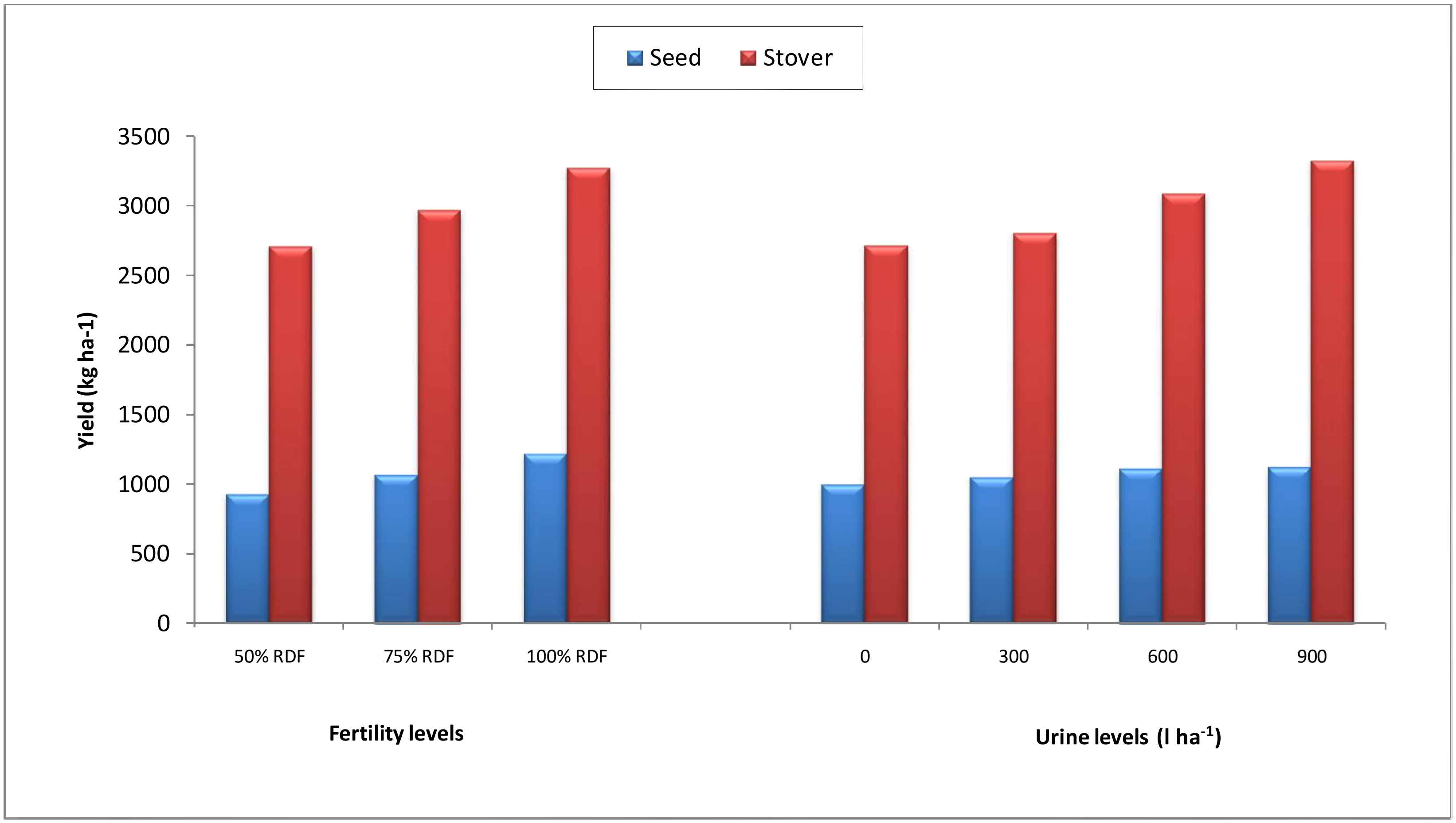


Fig. 5.7. Effect of fertility and cow urine levels on gross return and net return of mustard

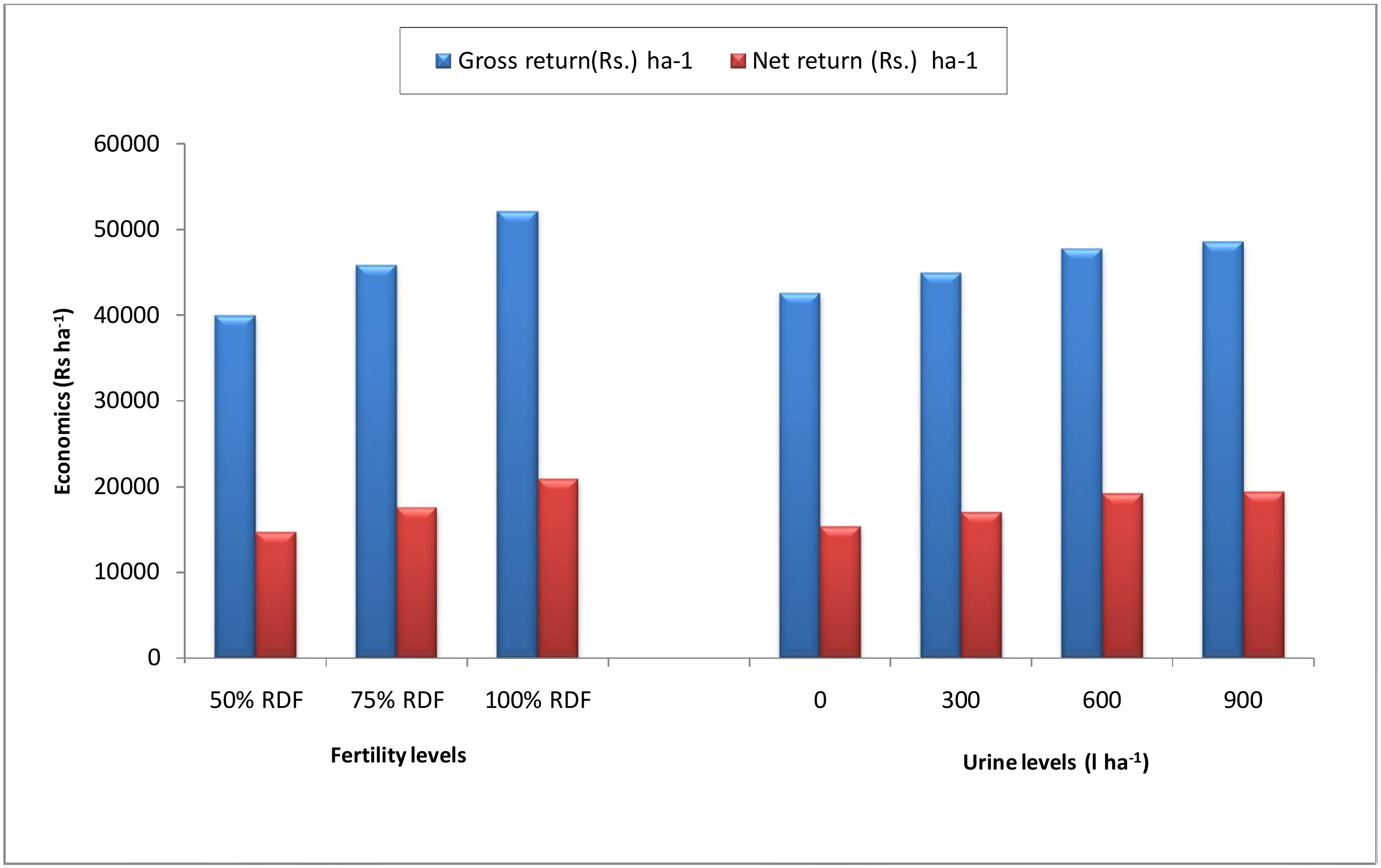


Fig. 5.6. Effect of fertility and cow urine levels on Seed and Stover yield of mustard

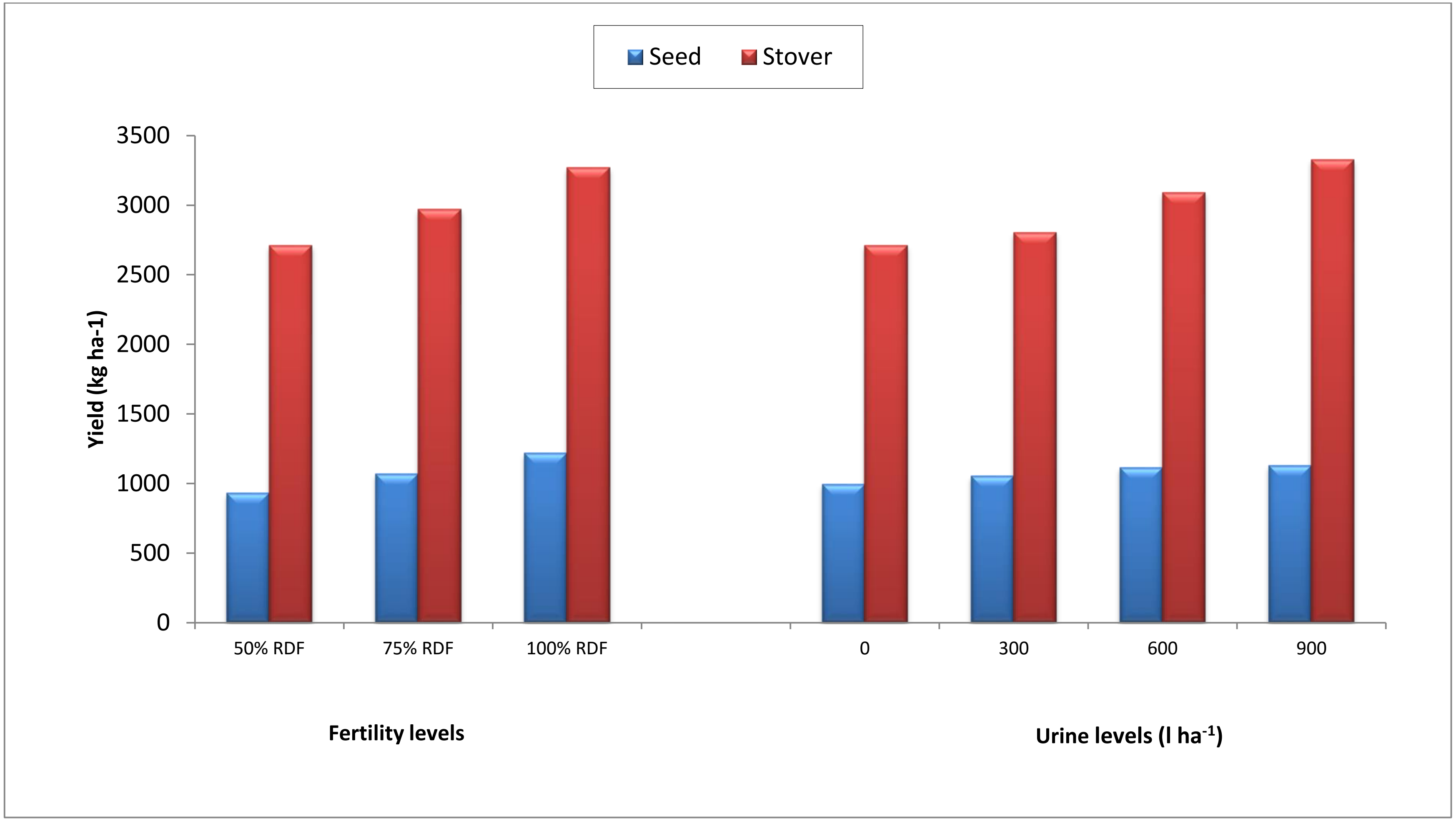
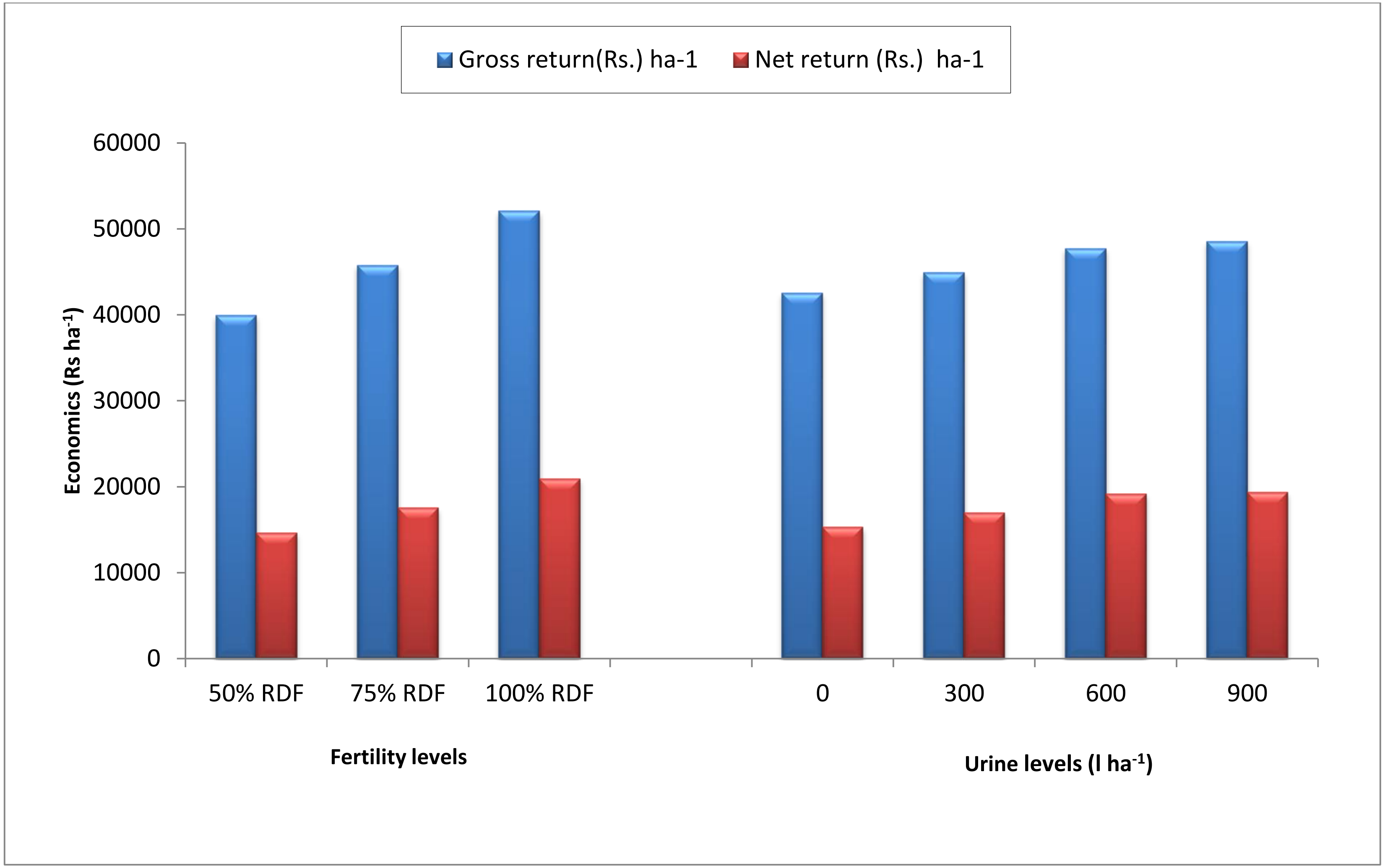


Fig. 5.7. Effect of fertility and cow urine levels on gross return and net return of mustard



Chapter V

DISCUSSION

The results of field studies obtained during the course of investigation are presented in preceding chapter. In this chapter, an attempt has been made to explain and substantiate the cause and effect relationship for justification of experimental findings, duly supported by available literature.

The growth and development (phenotype) of crop plant are directly related to their genetic constitution, though environmental factors and cultural practices do influence growth and development by their direct and indirect impact on different metabolic process of the plant (Gardner *et al.* 1988). Genetic constitution refers to specific plant character whereas the major environmental factors include soil-physical, chemical and biological properties along with climatic parameters like temperature, sunshine, rainfall etc. under a particular set of agro-climatic condition. Exploitation of maximum yield potential of crop depends on agronomic manipulation of local environment, specially the edaphic factors and growth of genotype for the advantage of crop plant.

Among the several agro-techniques that can raise the productivity of mustard, adequate nutrition holds the prime position. The role of integrated nutrient management is undoubtedly the most important factor among the agro- technique applied to enhance the productivity of mustard. The recent increase in mustard productivity has been mainly attributed to the increased use of inorganic fertilizers. Nutrient supplied exclusively through inorganic sources though increased yield initially, but sustainability in yield was not maintained over the years. Increasing use of inorganic fertilizers is adversely affecting soil health and environmental condition. Escalating fertilizers price in recent years, particularly that of P and K fertilizers is also adding to the declining factor productivity. Hence, need of a convenient and low cost technology, based on recycling of renewable sources was felt to meet the energy requirement for achieving augmented crop productivity as it is vital for availability of plant nutrients and maintenance of soil fertility.

In this chapter an attempt has been made to elucidate possible reason for variability obtained due to treatment difference on the basis of finding described in preceding chapter. The result obtained is discussed here in light of general principles of agronomy and established physiological and biological process. The results have been duly supported by references available in literature as and where necessary.

5.1 Effect of weather conditions on the growth and yield of mustard crop

A set of favorable environmental conditions is essential for proper growth and development of crop plant. Matching the crop phenology to the climatic environment which prevails during the growing season is an important aspect to exploit genetic yield potential. Mustard is a monocarpic annual in which growth and phenology are climate dependent. Rate of vegetative growth as well as floral initiation and anthesis, the vitally important components are easily affected by fluctuation in climatic parameters and may change the effectivity of agronomic management. Genetic responsiveness to photoperiod, temperature and humidity, affects the duration of flowering period, time of flower initiation and date of anthesis in mustard crop. Duration of crop growth is one of the main determinants of cumulative energy intercepted by the crop. Thus, sensitivity to photo-thermal regime establishes the time limit for energy input in crop. The meteorological data as well as regular field observations show that crop remained almost unaffected by weather variation except a few spells of mild moisture stress. The period between the first weeks of November to first week of January was almost dry. In second to third week of January 59.5 mm rain was received which coincided with the active growth stage and flowering stage of the crop. Again in second week of February 24.4 mm rainfall was received which proved useful for mustard for fruit development and seed filling.

Except few dry spells and unusual rain pattern the overall weather conditions were satisfactory but timely intercultural operations, irrigation and proper management practices minimized the adverse effect of weather on crop growth and development and finally yield of the crop.

As such the weather conditions were satisfactory which favoured proper growth and development.

5.2 EFFECT OF FERTILITY LEVELS

5.2.1 Effect of fertility levels on growth

Growth of plant can be measured vertically in terms of plant height and horizontally in terms of number of leaves, leaf area index, number of branches, dry matter accumulation etc. Dry matter accumulation is more important because all other vegetative characters are contained in it. Further, the growth characters *viz.*, plant height, number of functional leaves, leaf area index, dry matter accumulation, and number of primary and secondary branches plant^{-1} increased with the advancement in the age of mustard crop irrespective of treatments.

The increasing fertility levels up to 100 % markedly influenced the growth parameters viz. plant height, no of green leaf, leaf area index, leaf chlorophyll content in terms of SPAD value, dry matter production as well as phonological events. All the growth attributes improved with application of 100 % RDF at most of the growth stages during the experimentation. This supports the well established fact that combined application of nitrogen, phosphorus, potassium and sulphur in adequate quantity is beneficial for growth and development.

Nitrogen being constituent of cell plays a vital role in cell division and cell elongation by virtue of being the component of diverse type of metabolically active compounds like amino acid, proteins, nucleic acids, flavins, proteins, enzymes, co-enzymes and alkaloids. Therefore, it is vitally associated with activity of every living cell. Thus, greater availability of 'N' at higher doses might have improved the protein synthesis and photosynthesis leading thereby to rapid cell division and cell enlargement, which resulted into vigorous plant growth.

Phosphorus is a constituent of ADP and ATP plays a key role in energy transformation. It also helps in assimilation of photosynthetes into other metabolites and hence acts as an activity zone for CO_2 assimilation. Moreover, it is an integral part of chromosome. It stimulates cell division and necessary for meristematic growth. Therefore, adequate supply of P helps in faster growth of plant.

Potassium as an activator of enzymes is engaged in protein and carbohydrate metabolism. It also regulates carbohydrate translocation, synthesis of protein and maintenance of stability, stomata opening, membrane permeability and P^H control.

Sulphur application greatly influences chlorophyll synthesis, carbohydrate as well as protein metabolism and finally results in improvement in growth characters, contributing to higher dry matter accumulation in plants Willenbrink, (1967).

As such adequate and balanced supply of N, P, K, S at 100 % RDF to mustard favoured greater availability of these nutrients that ultimately resulted into enhanced growth of plants.

The optimistic result of increasing fertilizer doses on plant height, number of functional leaves, chlorophyll content and number of primary and secondary branches may be explained as N required for the formation of chlorophyll and P for synthesis of nucleic acids. Similarly, K is important for growth and elongation probably due to its function as osmoticum and may react synergistically with IAA responsible for growth and development. The vigorous growth of aerial organs at 100 % RDF may be due to high rate of synthesis of protoplasmic protein and in turn, protein synthesis increased the cell size, which is responsible for vertical development of plants Nova and Loomis, (1981). Similar effect of higher rates of fertilizer application to mustard has also been reported. This is in confirmation with the finding of Chaudhary *et al.* (2003); Khatkar *et al.* ,(2009) and Athokopam,(2010).

Increasing fertility levels from 50 to 100 % RDF favourably influenced the leaf area index (LAI) recorded at 60 DAS (Table 4.3). However, the 75 % and 100 % RDF remained comparable. It is possible that application of fertilizer (N, P, K, S) at higher rates might have enhanced tissue differentiation and expansion that resulted in taller plants and production of higher number of leaf $plant^{-1}$ with expanded leaves (Table 4.1 and 4.2). These results are in conformity with the findings of (Pradhan et al., 1997), Chaudhary *et al.* (2003).

Chlorophyll content of leaves recorded as SPAD values at 30 and 60 DAS increased with each increment of fertility level up to 100 % RDF (Table 4.3). This could be ascribed to the availability of the vital nutrient elements (N, P, K, S) at higher rates of fertilizer application. These results are in agreement with findings of Khatkar *et al.* (2009).

Shoot dry weight plant^{-1} increased markedly with increasing levels of fertility upto the highest level (Table 4.6). The balanced and adequate use of fertilizers at highest rate of application promotes plant growth parameters viz. plant height, green leaves plant^{-1}, LAI, branching and photosynthetic activity (chlorophyll content) that ultimately produced higher shoot dry weight. Athokpam (2010) also reported similar results.

5.2.2 Effect of fertility levels on yield attributes and yield of mustard

In the present investigation, yield attributing characters viz. siliqua on main shoot, siliquae plant^{-1}, length of siliqua, seeds siliqua^{-1} and 1000-seed weight were are markedly higher at higher rates of fertilizer application (Fig 5.1). However, for all the yield attributing characters, except the siliqua on main shoot the differences between 75 and 100 % RDF were not significant. The higher number of siliqua on main shoot at higher rates of fertilizer application is attributed to taller plant and thereby longer central axis at higher fertility level. The increase in siliquae plant^{-1}may be explained due increase in number of branches under higher fertility levels. With the application of higher rates of fertilizer, the tissue differentiations from the somatic to reproductive, meristematic activity and the development of floral primordia might have been enhanced causing greater production of flowers which latter developed to siliqua. Higher fertility levels is likely to induce greater translocation of photosynthates from leaves *via* stem to sink site i.e. siliqua and seeds. This resulted in bigger siliqua and more numbers of seed which on maturity becomes bold with highest test weight. These results are in accordance with the findings of Bohra *et al.* (1999) and Singh *et al.* (2000).

Increased NPKS levels enhanced the seed and stover yields significantly up to 100 % RDF. The highest yields increase were recorded under 100 % RDF followed by, 75 % RDF and 50 % RDF. Higher yields associated with higher levels of fertility were consistently observed because of enhanced growth and yield attributes. The positive response of mustard to applied nutrients up to 100 % RDF was also reported by Bohra *et al.* (1999), Singh and Butter (2006), Ghimire and Bana (2009)

The increase in yield due to application of nitrogen, phosphorus , potassium and sulphur in higer doses may be attributed to cumulative effect of increase in siliquae on main shoot, siliqua plant^{-1}, seeds siliqua^{-1}, siliqua length and 1000-seed weight. The results are in conformity with the findings of Bohra *et al.* (1999), Singh *et al.* (2000), Tomar *et al.* (2005), Singh and Butter (2006), Ghimire and Bana (2009), Paliwal and Singh (2014).

Harvest index of mustard was found to increase with increasing fertility levels from 50 to 100 % RDF (Table 4.9). However differences did not differ significantly. This shows that both the seed and stover utilized the applied nutrients at the same level of efficiency. These facts were also supported by Ghimire and Bana (2009).

5.2.3 Effect of fertility levels on quality of mustard

5.2.3.1 Effect of fertility levels on oil content and oil yield

Oil content of seed was decreased with reducing levels of fertility from 100 to 50 % RDF (Table 4.10). However, the difference was significant only between 100 % and 50 % RDF. The maximum seed oil content at highest fertility level is attributed to the adequate availability of nutrients particularly that of sulphur. Similar results have been reported by Kachroo and Kumar (1999).

The improvement in seed oil content with increasing rates of fertility might be due to the role of sulphur in the formation of acetyl Co-A, a precursor compound for synthesis of long chain fatty acids. Besides this sulphur is the constituent of a multi enzyme complex “fatty acid synthetase’’ that plays an important role in oil synthesis. Increased oil yield accompanied with higher seed yield at higher levels of fertility ultimately enhanced the oil yield (Table 4.10). Similar findings were reported by Singh (1983), Sadhu *et al.* (1997); Tomar *et al*. (1997); Singh and Singh (2005); Bhat *et al.*, (2006).

5.2.3.2 Effect of fertility levels on protein content and protein yield

Seed protein content of mustard was also increased with increasing fertility levels up to 100 % RDF (Table 4.10), though 50 % and 75 % RDF remained comparable. This could be ascribed mainly to the greater availability of nitrogen and sulphur at higher fertility levels as there exists direct relationship between nitrogen content and protein content in plants and sulphur is a constituent of three amino acids viz. cysteine, cystine and methionine. The protein yield is the resultant effect of seed yield and protein content. Therefore, the higher protein yield with increasing fertility levels is justified. These findings are in agreement with those of Kachroo and Kumar (1999); Singh *et al.* (2008).

5.2.4 Effect of fertility levels on nutrient content and uptake

Nitrogen, phosphorus, potassium contents in seed and stover increased with increasing fertility level up to 100 % RDF (Table 4.11). However, the difference was significant only for N content of seed between 50 and 100 % RDF. This could be attributed to the greater availability of nitrogen at higher rates of application. In general, higher concentration of N, P and K were recorded in seed than straw suggesting efficient translocation of nutrients to the sink i.e. seed. Application of higher levels of fertilizers (NPKS) assured the availability of nutrients in adequate amount. Hence, at 100 % RDF, there was more healthy and vigorous plant growth as evident by taller plants, more number of leaf, branch, LAI and dry matter production. This accompanied with better nutrient contents which resulted in significantly higher nutrient uptake by seed and stover with increasing fertility levels up to 100 % RDF(Table 4.11). These results are in close conformity with the findings of Dixit and Gautam (1996), Tomar *et al.* (2005) and Bohra *et al.* (2006). Nitrogen, phosphorus and potassium uptake were positively influenced by adequate supply of nutrients. The release of nutrient in soil solution depends upon intensity and capacity of soil to supply these nutrients. Adequate supply of nutrient increased nitrogen, phosphorus and potassium content for their effective uptake.

5.3 EFFECT OF URINE LEVELS

5.3.1 Effect of cow urine levels on growth of mustard

In present investigation lucid effect of cow urine application was noticed on growth attributing character of mustard viz. plant height, no of functional leaves plant^{-1}, primary and secondary branches plant^{-1}, chlorophyll content (SPAD), LAI, dry weight of shoot plant^{-1} at all stages of crop growth during the experimentation.

However, the effect of urine application on growth attributing characters was more pronounced at 900 l. ha^{-1} followed by 600 l. urine ha^{-1} (Table 4.1 to 4.6).

The growth attributing characters improved probably due to better supply of Nitrogen at higher rates of urine application. Besides this the different enzymes and hormones present in cow urine are also responsible for the better growth of plant Vahanka *et al*. (2010). Nitrogen, the most deficient element in Indian soils, the major constituent of cell and plays a key role in plant metabolism by virtue of being essential constituent of diverse types of metabolically active compounds like amino acids, proteins, nucleic acids, prophyrins, flavins, purine, pyrimidine, nucleotides, enzymes, co-enzymes (Agrawal and Sharma, 1976). Hence, it is associated with the activity of every living cell. The chemical analysis of the cow urine applied in the present investigation showed to contain 0.978 % N, 0.0917 % P, 0.11 ppm K, Ca 0.80 ppm and Mg 3.21 ppm. Therefore more availability of N at higher rates of cow urine application has favoured protein synthesis and greater SPAD values (Table 4.3) indicate increased leaf chlorophyll content and thereby higher photosynthesis. Potassium, the other constituent of cow urine (0.11 ppm) as an activator of enzymes regulates carbohydrate metabolism and protein synthesis; it also controls P^{H}, stomatal opening and membrane permeability. Besides N and K, the urine application at higher rates might have also improved the supplies of phosphate, sulphate, Ca, Mg and micronutrients as well. This might have led to rapid cell division and enlargement, which ultimately resulted, into vigorous plant growth. The findings of present investigation is in conformity with the findings of Kumar *et al*. (1997), During & McNaught, (1961) Joblin & Keogh (1979).

Cattle urine is also known to supply minerals, hormones and enzymes useful to plant growth and development Vahanka *et al*. (2010). Adequate supply of urine promotes differentiation and expansion of tissues resulting in the production of more no of functional leaves $plant^{-1}$. In the present study it is also possible that taller plants and increased branching at higher levels of urine have helped the plants in producing higher no of functional leaves per plant, LAI, leaf chlorophyll and there by higher dry matter production (Table 4.2, 4.3 and 4.6).

5.3.2 Effect of cow urine levels on yield attributes and yield of mustard

Yield attributing characters viz. siliquae on main shoot, siliqua plant^{-1}, seeds siliqua^{-1}, siliqua length, 1000 seed weight and seed yield plant^{-1} are presented in Table 4.10. All the yield attributing characters were positively influenced by increasing levels of urine. The results are in close conformity with the findings of Khanal *et al.* (2010); Vahanka *et al*. (2010); Singh *et al*. (2014).

As nitrogen is one of the major component of cow urine, its application has been found to enhance the process of tissue differentiation, cell multiplication, cell enlargement i.e. from somatic to reproductive phase, meristematic activity and development of floral primodia leading thereby to increased flowering and ultimately the fruit setting. As a result of this, higher siliqua plant^{-1} was obtained with increasing levels of urine application up to highest level (900 l ha^{-1}). Moreover, the taller shoot produced under the influence of higher doses of urine, enabled the plants to bear higher number of siliqua on main shoot which is considered to be the major determinator of mustard seed yield.

As nitrogen and potassium both are involved in protein synthesis and K helps in the translocation of photosynthates to sink, under adequate urine supply, there would have been greater translocation of photosynthates from source to sink leading thereby to production of bigger siliqua with more number of seeds (Fig. 5.4). The favourable effect of urine on yield attributing character viz. siliquae on main shoot, siliqua plant^{-1}, seed siliqua^{-1}, siliqua length and 1000 seed weight was reflected on seed yield plant^{-1} and seed yield ha^{-1}. (Fig. 5.5) Consiquently, the seed yield was increased significantly with increasing levels of urine application up to 900 l ha^{-1}. The results are in agreement with the findings of (Mohanty *et al.* 2014); Oliveira *et al.* (2009) and Singh *et al*. (2014).

Increasing levels of urine application from 0 to 900 l ha^{-1} favorably improved the stover yield. Higher urine levels produced taller plants and increased no of functional leaves plant^{-1}, primary and secondary branches plant^{-1} and accumulation of dry matter plant^{-1} which ultimately resulted into higher stover yield. This observation confirms the findings of Ledgard, *et al.* (1982) and Saunders (1987).

The harvest index was slightly improved with the application of 300 l urine ha^{-1} but there after it declined with increasing levels of urine application up to highest level and the decline in harvest index between 300 and 600 l urine ha^{-1} was significant. This shows that at higher levels of urine application, the translocation of photosynthates to the sink was not efficient that favoured more to the stover production than seed.

5.3.3 Effect of cow urine levels on quality of mustard

Quality parameter includes oil percentage, oil yield, protein content etc. Synthesis of oil by plant organs is a complicated series of bio-chemical reactions. Certain intermediate compounds which formed as a result of oxidation of carbohydrates are utilized in the synthesis of oil and fats. Rapid inter conversion takes place in living cell, the glycerol and fatty acids are final components which are derived from carbohydrates during respiration. During maturation of oilseeds, an increase in seed oil content occurs concurrently with a decrease in the quantity of carbohydrate present which suggests that carbohydrates in seeds are being converted in to fat.

Oil yield of mustard improved markedly with increasing levels of urine application from 0 to 900 l urine ha^{-1}. (Fig. 5.6) As regards the urine application, protein content of mustard seed improved with increasing levels of urine application from 0 to 900 l urine ha^{-1}. This could be attributed nutrients availability particularly the sulphates, under the highest level of cow urine application (Ledgard *et al.* 1982). The role of sulphur in enhancing the oil content of oil seeds in general and mustard in particular is well documented[Kachroo and Kumar (1999); Yadav *et al.* (2005); Singh *et al.* (2008)].

As cow urine is known to promote the nitrogen uptake, higher levels of urine application resulted in increased seed protein content and protein yield in plants. Similar results were shown by Khanal *et al.* (2010) and (Mohanty *et al.* 2014).

5.3.4 Effect of urine levels on nutrient content and uptake of mustard

As regards the cow urine application, seed N, P and K content increased with increasing levels of urine applications from 0 to 900 l urine ha^{-1}. However, the differences were significant with respect to N content of seed and stover (Table 4.11). This shows more efficient utilization of cow urine by mustard. This supports the finding of (Mohanty *et al.* 2014).

Increasing levels of cow urine application from 0 to 900 l ha^{-1} also enhanced the uptake of nitrogen, phosphorus and potassium both by seed and stover. This could be ascribed to the better nutrient contents and higher seed and stover yield at higher fertility levels. Urine increased the N concentration of crop (particularly the nitrate fraction) and increased the potassium concentration of crop. By the application of cow urine, soil microorganism population increased along with the crop yield. So, it may be possible that N, P, K uptake by crop increased as there were lots of enzymes are secreted by the microbes. These results are in conformity with Vahanka *et al*. (2010), Singh *et al*. (2014).

5.4. Comparative economics

In modern agriculture, crop production is taken as business. Therefore, based on the experimental results, the practices giving maximum net return under particular set of condition can only be recommended to the farmers. Under present investigation large variations were noticed for gross return and cost of cultivation under different fertility and urine levels. The differences in gross return under various fertility and urine levels were mainly due to the differences in seed and stover yield. Whereas the cost of cultivation was varied due to different quantities of fertilizer and urine applied.

Increasing fertility levels significantly enhanced the gross return up to highest level (100 % RDF). However, the cost of cultivation was also increased with each increment in fertility level due to larger quantities of fertilizers and urine applied. The net return also increased with increasing levels of fertility up to highest level. However, 75 and 100 % RDF remained comparable with respect to net return. (Fig. 5.7) Benefit: cost ratio also followed similar trend. This shows that 100 % RDF was more remunerative over lower levels of fertility. Gross return and net return were also increased with increasing levels of urine application from 0 to 900 l ha^{-1}. Nevertheless, the difference between 75 and 100 % RDF remained at par both for gross as well as net return. This shows that though seed and stover yield did not differ significantly between 600 and 900 l urine ha^{-1} but due to better market price of produce, application of cow urine at 900 l ha^{-1} was more remunerative than lower levels. However, the benefit: cost ratio increased with increasing levels of urine application up to 600 l ha^{-1} but thereafter declined. Urine levels at 600 and 900 l ha^{-1} being at par recorded significantly higher benefit: cost ratio than control. This shows that profit earned per unit of investment was more with the use of 600 and 900 l urine ha^{-1}. This is in conformity with the findings of Gupta and Yadav (2001).

Chapter VI

SUMMARY AND CONCLUSION

The present investigation entitled **"Effect of fertility levels and cow urine application on growth, yield, and quality of Indian mustard [*Brassica juncea* (L.) Czernj. & Cosson]"**was carried out at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi during the winter (*rabi)* season of 2013-14 with the following objectives:

1. To study the effects of fertility and cow urine levels on growth, yield and quality of Indian mustard.

2. To study the treatment effect on nutrient uptake.

3. To work out the economics of various treatments.

The soil of experimental site was Gangetic alluvial having sandy clay loam texture with *p*H 7.8. Experimental soil was moderate in fertility with organic carbon of 0.38 and available nitrogen content being 138.48 kg ha^{-1}, available phosphorus (23.31 kg ha^{-1}) and available potassium (172.10 kg ha^{-1}) in soil. The experiment was laid out in split plot design. The main plot treatment consisted three fertility levels i.e. 50%, 75% and 100% RDF (Recommended fertilizers dose) whereas four levels of cow urine i.e. 0, 300, 600, 900 l ha^{-1} were allocated to sub-plots. To maintain homogeneity water @ 900, 600, 300, and 0 l ha^{-1} was added to the urine levels i.e. 0, 300, 600, 900 l ha^{-1} respectively. The total numbers of treatment combinations were twelve. The treatments were replicated thrice to avoid any effect of heterogeneity. The treatments within main plots and sub-plots were randomly allocated in each replication as per standard procedure. So the total numbers of plots in the experiment were 36.

Application of nitrogen phosphorus, potassium and sulphur were made through the urea, di-ammonium phosphate, muriate of potash and elemental sulphur, respectively. Fresh cow urine was collected from the IFS unit of Agricultural Research Farm of the Institute of Agricultural Sciences, B.H.U. The maximum recorded temperature during the experiment was 31.9 °C in the 12th standard week (March) whereas; the lowest minimum temperature remained 9.8 °C in the month of January. The total rainfall received during the crop period (Nov 5 to March 25) was 134.4 mm. Irrigation was applied depending upon requirement as per standard practice. Effective rainfall was also taken into consideration for scheduling irrigation. Other crop management practices were followed as per the recommendation of the area.

Response to fertility and cow urine levels were measured in terms of various quantitative and qualitative expressions. Growth and yield attributing characters studied were plant height (cm), functional leaves plant^{-1}, leaf area index, chlorophyll content (SPAD) dry matter accumulation, number of primary and secondary branches, siliquae plant^{-1}, siliqua on main shoot, siliqua length, seeds siliqua^{-1} and 1000-seed weight. Seed and stover yields (kg ha^{-1}) were also recorded. Oil and protein contents were estimated to assess the effect of treatments on qualitative aspects. Oil and protein yields were determined by simple calculations. Nitrogen, phosphorus and potassium contents in seed and stover were also estimated and total removal of nitrogen; phosphorus and potassium were worked out.

The data collected during the course of experimentation were subjected to statistical analysis to draw valid conclusions. Finally the different treatments were assessed for their gross return, net return and output input ratio. The important findings and broad conclusion emerging from the investigation are summarized hereunder.

6.1 Effect of fertility and cow urine levels on growth parameters

Plant growth parameters *viz.*, plant height, functional leaves plant^{-1}, leaf area index, dry matter accumulation, number of primary and secondary branches were immensely influenced by nutrient management. Plant height, functional leaves plant^{-1}, leaf chlorophyll content (SPAD value), leaf area index, dry matter accumulation and primary and secondary branches plant^{-1} increased with increasing fertility and cow urine levels. The value of all these growth parameters improved significantly at 100 % RDF. The next best fertility level with respect to growth parameters is 75 % RDF.

Lucid effect of cow urine application was noticed on growth attributing character of mustard *viz*. plant height, no of functional leaves plant^{-1}, primary and secondary branches plant^{-1}, shoot dry weight plant^{-1} at all stages of crop growth. Leaf chlorophyll content at 30 and 60 DAS as well as LAI at 60 DAS also increased with increasing urine levels up to 900 l ha^{-1} though remained at par recorded significantly higher values of growth attributing character than control at different stages.

6.2 Effect of fertility and cow urine levels on yield attributes and yield of mustard

The yield attributes *viz.*, siliquae plant^{-1}, siliqua length, seeds siliqua^{-1} and 1000-seed weight increased with increasing fertility levels up to 100 % RDF. All the yield attributing character and yield increased significantly from lowest to highest fertility level. Application of 100 % RDF produced 12.1 and 31.2 % higher seed yield than 75 % and 50 % RDF respectively.

As regards the urine application, the increasing levels of urine application up to 900 l cow urine ha^{-1} enhanced the yield attributes as well as seed and stover yield. Nevertheless, for most of the characters the differences between 0 and 300 l ha^{-1} and 600 and 900 l ha^{-1} were not significant.

6.3 Effect of fertility and cow urine levels on quality parameters of mustard

Increasing levels of fertility resulted in corresponding increase in oil content from 50 to 100 %. However, the increase in seed oil content was significant only between 50 to 100 % RDF. Fertilizer application also resulted marked improvement in oil yield that increased significantly with increasing fertility levels. The maximum oil yield of 450 kg ha^{-1} was obtained with highest fertility level that recorded 16.3% and 36.4% higher oil yield than 75 % and 50 % RDF, respectively.

As regards the urine application, seed oil content and oil yield of mustard improved markedly with increasing levels of urine application from 0 to 900 l urine ha^{-1}. But oil content and oil yield did not differ significantly between 600 and 900 l cow urine ha^{-1}.

Increasing fertility levels from 50 to 100 % RDF correspondingly enhanced the seed protein content. However, the significant improvement in seed protein content was noticed only between 50 and 100 % RDF. However, increasing fertility levels from 50 to 100 % RDF caused significant increase in protein yield and all the fertility level differed significantly.

Protein content of mustard seed improved with increasing levels of urine application from 0 to 900 l urine ha^{-1}. However, significant difference was observed only between 0 to 900 l urine ha^{-1}. The protein yield (kg ha^{-1}) of mustard improved with increase in urine levels up to 900 l/ha. Application of 600 and 900 l urine ha^{-1} though remained at par recorded significantly higher protein yield than lower level of cow urine application.

6.3 Effect of fertility and cow urine levels on nutrient content and uptake by mustard

In this context, the N, P, K content of mustard seed and stover increased with increasing levels of fertility. However, significant difference between 50 and 100 % RDF was noticed only for N content of seed.

As regards the cow urine application, N content in seed and stover increased with increasing levels of urine applications from 0 to 900 l urine ha^{-1}. Similarly, P and K content in seed and stover was also increased with increasing levels of urine application from 0 to 900 l urine ha^{-1} but the differences between any two levels remained comparable.

Nitrogen, phosphorus and Potassium uptake by seed and stover decreased markedly with decreasing levels of soil fertility from 100 to 50 % RDF. Increasing levels of fertility from 50 to 100 % RDF correspondingly improved N, P and K uptake by stover.

Similarly, increasing levels of cow urine application from 0 to 900 l ha^{-1} increased significantly N, P and K uptake by seed and stover but the differences were significant only between 0 and 600 and 0 and 900 l urine ha^{-1}.

6.4 Effect of fertility and cow urine levels on the economics of mustard

The gross return increased significantly with increasing fertility levels from 50 % to 100 % RDF. Net return also followed similar trend but the significant difference was observed only between 50 % and 100 % RDF. Benefit: cost ratio also increased with each increment in fertility level but the differences were not significant.

Increasing levels of cow urine application from 0 to 900 l ha^{-1} registered corresponding increase in gross as well as net return. All the urine levels differed significantly except 600 and 900 l urine ha^{-1}. Application of 600 l urine ha^{-1} being at par with 900 l ha^{-1} recorded significantly higher benefit: cost ratio than lower levels.

Conclusion

On the basis of the experimental findings of present investigation following conclusions are drawn:

No curtailment in the recommended fertilizer dose (120 kg N + 60 kg P_2O_5 + 60 kg K_2O + 40 kg S ha^{-1}) to mustard is possible.

Cow urine application up to 900 l ha^{-1} enhanced the growth, yield and quality of mustard.

Application of 100 % RDF and 900 l urine ha^{-1} was found remunerative.

6.5 Recommendation

On the basis of economic analysis of experimental findings, it is recommended that 100 % RDF and 900 l urine ha^{-1} should be applied to mustard.

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Appendix - 1

General cost of cultivation (Rs ha^{-1}) of Mustard

S. No.	Operations Materials	Input	Rate (Rs.)	Cost (Rs.)
1	Field preparation			
(a)	Discing	One tractor (45HP) for 2 h	400/h	800
b	Cultivation with double cultivator(twice)	one tractor (45HP) for 4 hrs	400/h	1600
2	Layout	4 man days	150/ man day	600
3	Sowing with Kudal	22 man days	150/ man day	3300
4	Seed	5 kg	60 / kg	300
5	Thinning	8 man days	150/ man day	1200
6	Weeding			
(a)	Chemical Weeding	Pendimethalin @3.3lit /ha	300/lit.	990
(b)	Mechanical Weeding	8 man days	150/ man day	1200
7	Irrigation (2) (1 pre + 1 post)	Water for 2 irrigation	350 /irrigation	700
	Labour charge	4 man days	150/ man day	600
8	Plant protection	-	-	
(a).	2 spraying against aphid	Rogor 25 EC 2 Litre	370 /lit.	
(b).	2 spraying against alternaria blight	Dithane M 45 4 kg	200 / kg	800
	Labour charges	4 man days	150/ man day	600
10	Harvesting	15 man days	150/ man day	2250
11	Bundle making,Threshing and Winnowing	15 mandays	150/ mandays	2250
			Total	**17190**

Appendix – 1I

Cost of cultivation (Rs ha^{-1}) for various combinations of fertility and cow urine levels.

Sno.	Treatments	General Cost of cultivation	Fertilzer and urine price	Total Working Capital	Interest on working capital (14%/annum)	Land Revanue (Rs.120/annum)	Total Cost of cultivation
1	F_1U_0	17190	5485.6	22675.6	1587.292	60	24323
2	F_1U_1	17190	6085.6	23275.6	1629.292	60	24965
3	F_1U_2	17190	6685.6	23875.6	1671.292	60	25607
4	F_1U_3	17190	7285.6	24475.6	1713.292	60	26249
5	F_2U_0	17190	8221.6	25411.6	1778.812	60	27250
6	F_2U_1	17190	8821.6	26011.6	1820.812	60	27892
7	F_2U_2	17190	9421.6	26611.6	1862.812	60	28534
8	F_2U_3	17190	10021.6	27211.6	1904.812	60	29176
9	F_3U_0	17190	10971.3	28161.3	1971.291	60	30193
10	F_3U_1	17190	11571.3	28761.3	2013.291	60	30835
11	F_3U_2	17190	12171.3	29361.3	2055.291	60	31477
12	F_3U_3	17190	12771.3	29961.3	2097.291	60	32119