

**RESPONSE OF POTATO CULTIVARS
TO VARYING LEVELS OF NITROGEN
AND PHOSPHORUS FERTILIZATION**

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DIVISION OF OLERICULTURE

THESIS

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DEDICATED TO

THE SERVICE OF MANKIND

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UNIVERSITY OF AGRICULTURAL SCIENCES
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TECHNOLOGY OF KASHMIR**

CERTIFICATE- I

This is to certify that the thesis entitled “**Response of potato cultivars to varying levels of nitrogen and phosphorus fertilization**” submitted in partial fulfilment of the requirements for the **Degree of Master of Science in Agriculture** (Olericulture) to the faculty of Post Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir is a record of bonafide research carried out by **Mohammad Maqbool Bhat(Regd. No. 2001-A-645-M)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that such help or assistance received during the course of investigation has been duly acknowledged.

Endorsed

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We, the members of Advisory committee of **Mohammad Maqbool Bhat**, a candidate for the **Degree of Master of Science in Agriculture**. (Olericulture), have gone through the manuscript of the thesis entitled “**Response of potato cultivars to varying levels of nitrogen and phosphorus fertilization**” and recommend that it may be submitted by the student in partial fulfillment of the requirements for the degree.

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Dated:.....

(Mohammad Maqbool Bhat)

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**SHER-E-KASHMIR
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A B S T R A C T

The present investigation was carried out at vegetable Experimental Farm. Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar Campus during Kharif 2002 to find out the optimum dose of nitrogen and phosphorus for potato cultivars. The experiment was laid out in split plot design with the three replications. The potato cultivars viz. PP-2500, PP-48 and Kufri Jyoti were planted in the main plots with a spacing of 60 x 20 cm, while combinations of three levels of each, nitrogen (120, 160 and 200 kg ha⁻¹) and phosphorus (80, 100 and 120 kg ha⁻¹) were tried in sub plots.

The observations were recorded on percent emergence, plant height, number of shoots plant⁻¹, tuber number plant⁻¹, average tuber weight, tuber weight plant⁻¹, tuber yield q ha⁻¹, tuber yield in grades plant⁻¹, dry matter percentage and benefit-cost ratio.

Analysis of variance revealed that main effects of cultivars, nitrogen and phosphorus were significant for morphological, yield and yield attributing traits and dry matter content except the effects on production of

“C” grade tubers (<25g), the effect of nitrogen and phosphorus on plant emergence and the effect of phosphorus on number of shoots plant⁻¹.

The interaction effects of cultivar x nitrogen were found significant for plant height, tuber number plant⁻¹, average tuber weight, tuber weight plant⁻¹, tuber yield q ha⁻¹ and production of “A” and “B” grade tubers while as interaction effects of nitrogen x phosphorus were found significant for tuber number plant⁻¹, average tuber weight, tuber weight plant⁻¹ and tuber yield q ha⁻¹.

Application of nitrogen and phosphorus indicated a linear and significant increase in plant height and number of shoots plant⁻¹ at 120- 200 kg N ha⁻¹ and 80- 120 kg P₂O₅ ha⁻¹ in all the three cultivars. While a significant increase in tuber number plant⁻¹, average tuber weight, tuber weight plant⁻¹, tuber yield, and dry matter content was observed upto 160 kg N and 100 kg P₂O₅ ha⁻¹, and thereafter a decrease was observed at 200 kg N and 120 kg P₂O₅ ha⁻¹, respectively in all the cultivars.

Significant increase in the tuber yield from 264.86 q ha⁻¹ to 314.26 q ha⁻¹ was observed when the level of nitrogen was increased from 120- 160 kg ha⁻¹ and further increase in the level of nitrogen upto 200 kg ha⁻¹ significantly decreased the tuber yield to 269.39 q ha⁻¹. Similarly a significant increase in the tuber yield from 280.81 q ha⁻¹ to 290.78 q ha⁻¹ was observed when the level of phosphorus was increased from 80- 100 kg ha⁻¹. But again at the higher dose of 120 kg P₂O₅ ha⁻¹ the tuber yield significantly decreased to 274.93 q ha⁻¹. Among the cultivars PP-48 proved superior with respect to growth, yield and yield components and quality followed by PP-2500 and Kufri Jyoti.

The economic studies indicated that the treatment combination of 160 kg N and 100 kg P₂O₅ ha⁻¹ with constant dose of 100 kg K₂O produced the highest benefit-cost ratio which was recorded as 1.39 in PP-48, 1.23 in PP-2500 and 1.03 in Kufri Jyoti. Thus from the present investigation, it is concluded that a fertilizer combination of 160 kg N and 100 kg P₂O₅ with constant dose of 100kg K₂O ha⁻¹ was found optimum for obtaining higher and economic returns of the potato cultivars under Kashmir valley conditions.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most important food crops both in developed as well as in developing countries. Due to its diversified uses as food, feed and raw material for producing starch and alcohol in the developed countries, the potato is generally thought to be a crop mostly confined to these nations.

The potato is known for sustaining millions of lives by providing cheap food and nutrition during the times of war and hunger. This crop is of special significance to the developing countries as it has high production potential per unit area and time with high nutritional value to sustain burgeoning population and ward off malnutrition and hunger. Potato is a balanced food containing less energy but substantial quantity of high quality proteins, essential vitamins and minerals (including trace elements). Besides being nutritive, potatoes have several medicinal properties. The medicinal value of potatoes are a bonus to potato lovers; (Ezekiel and Khurana, 2003)

In order of importance for food production among twenty major food crops, (on fresh weight basis) potato ranks 6th in the developing countries, 4th in the developed countries, 4th in all world and 3rd in India. (Anonymous, 1999).

The potato is a native of high Andean region of South America. It was introduced in the Europe during the second half of 16th century by the Spanish seamen. From Spain it spread

throughout Europe where it became a popular food during the middle of 18th century. From Europe it spread to all other parts of the world. It has the potential to acclimatize in a wide array of climatic conditions from temperate to tropical and almost every country cutting across the barriers of latitude and longitude.

Either Portuguese or the Britishers introduced it in India perhaps in late 16th or early 17th century. By the 19th century, this crop was widely grown throughout the country. Potato in India is grown in very diverse agroclimatic conditions that range from snowline to seashore. In India potato can be grown throughout the year in one part or the other. Its adaptability is so wide that traditional agriculture seasons do not restrict its cultivation. In fact it can grow and give economic returns under any climate, provided the night temperatures during tuberization remain around 20C⁰. (Shekhawat *et al*, 1999).

Today, India is the third largest producer of potato in the world and potato production in the country has crossed 25 million tonnes and is expected to increase further. (Ezekiel and Khurana, 2003).

In Jammu and Kashmir, potato is grown from subtropical to extreme cold temperate conditions. In Kashmir valley it is cultivated on an area of 1500 hectares with a production of 30,000 tonnes. (Anonymous, 2000).

Manurial and mineral requirements of the potato crop are quite high because of its high yield potential per unit area and time. The application of fertilizers and organic manures is thus essential to obtain economic yield. Therefore for a good vegetative growth and better tuberization, (which leads to good yield) the application

of adequate quantity of fertilizers is essential, besides application of organic manures. Nitrogen, Phosphorus and Potassium are the macronutrients required for potato production and it is impossible to raise a successful crop without the fertilizers. But at the same time it must be recognized that the fertilizers are becoming scarce and costly item because of energy crisis. The efficient use of fertilizers has therefore assumed special significance from national and farmers point of view and to reduce the cost of production.

Potato needs nitrogen, phosphorus and potassium in suitable combinations and at optimum levels for obtaining higher yield. Variable response to nitrogen phosphorus and potassium have been reported and the responses were observed to vary with a number of factors like soil, climate and varieties etc. (Singh and Sharma, 1992; Lal and Arora, 1993; Grewal *et al*, 1991).

The information on this aspect is scanty especially for the crop grown under Kashmir valley conditions. Thus present study entitled “Response of potato cultivars to varying levels of nitrogen and phosphorus fertilization” was undertaken to generate the information of academic and practical value keeping into consideration the following objectives: -

1. To assess the effect of different levels of nitrogen and phosphorus on growth yield and yield attributes of some high yielding potato cultivars,
2. To quantify the optimum level of nitrogen and phosphorus for these potato cultivars, and
3. To work out relative economics of different cultivars *visa-a-vis* monetary inputs.

REVIEW OF LITERATURE

The yield and quality of crop plants is the net result of its genetic potential, input management and environmental interactions. Amongst the inputs management, nitrogen and phosphorus fertilizers are of paramount importance. Nitrogen and phosphorus needs of the potato crop are known to vary with a number of factors viz. agroclimate, variety, soil type, kind of fertilizers, their time and method of application, nutrient interaction and moisture supply. Nitrogen is the most limiting factor in most of the soils and the need for its application in one or other form is well recognized in all vegetables and other farm crops. Nitrogen increases tuber yield primarily by stimulating root growth, crop emergence, top growth and tuber growth. Phosphorus enters into the structural composition of plant and increases tuber yields by improving the size as well as number of tubers. Inadequacy of nitrogen decreases the yields by reducing the plant growth including height of plant, number and size of leaves and continued nitrogen starvation leads to even dropping of leaves particularly lower ones. As a result of this, there is a decrease in photosynthetic area. Excessive amounts of nitrogen application may also reduce the yields by interfering with translocation of photosynthates from source to sink (leaves to tubers). Plants with sufficient nitrogen are

characterized by vigorous plant growth, increased leaf area index and large tuber size as well as its number.

Phosphorus is mobile nutrient in plant system, so its inadequacy, if any, is reflected in the form of symptoms in the young growing parts of plant. Phosphorus deficiency often results in lusterless curled leaves with purple pigmentation and some times marginal scorching exhibited right from the early stages of plant growth. Phosphorus is known to participate in a number of biological reactions such as energy transfer, carbohydrate metabolism vis-à-vis for the development of roots, tops and improving food value of crop.

The literature pertinent to the present investigation has been reviewed in this chapter with the objective of evaluating critically the research work done on the “Response of potato cultivars to varying levels of nitrogen and phosphorus fertilization”.

2.1.1 Effect of nitrogen on plant growth.

Jaisinghani *et al*, (1964) reported that the potato crop showed more positive and significant response to nitrogen application. Theron *et al*, (1965) observed that nitrogen expressed direct effect on growth and development of potato crop and excessive nitrogen reduced tuber set.

Das and Ghosh (1973) found relative increase in plant height, number of leaves, total leaf area, number of tubers per plant and mean fresh weight per tuber at higher levels of nitrogen. They also reported that increase in the level of nitrogen increased the leaf area index and net assimilation rate. Sah and Sahay (1974) reported that with the increase in dose of nitrogen there was significant increase in the height of the plant. The plant height increased progressively with

successive increase in the levels of nitrogen upto 150 kg ha^{-1} at earlier stages of growth.

Mandal and Arora (1975) reported that in general, nitrogen had no influence on the germination percentage, which was slow in the initial stages but within 15 days the germination was 95 percent.

Pushkarnath (1976) observed that the application of nitrogen increased stem thickness which was closely related to the size of tuber. He also reported that root growth was directly related to nitrogen supply and increase in top growth was directly related to the level of nitrogen applied.

Santeliz *et al*, (1981) while studying the effect of different levels of nitrogen on the variety Kennebec, found that increase in the nitrogen level increased leaf area, dry matter of leaves, stem and tubers but maturity was delayed and tuber yield and tuberization depressed at higher rates of nitrogen.

Singh *et al*, (1986) observed that potato responded well to the application of nitrogen upto 120 kg ha^{-1} along with 50 kg ha^{-1} .

Sahota and Perumal (1986) reported that plant height increased progressively with successive increase in levels of nitrogen upto 120 kg ha^{-1} . It also increased number of shoots hill⁻¹ and the number of leaves per plant⁻¹.

Sharma & Grewal (1987) found that placement of high dose of urea in furrows (more than 60 kg ha^{-1}) at planting had an adverse effect on plant emergence.

Anand and Krishnappa (1988) reported that application of nitrogen and potassium and their interaction had non significant effect on plant height and number of shoots hill⁻¹.

Sharma and Singh (1988) observed that increase in the rate of N and P application significantly increased plant height upto 120 kg N ha⁻¹. Number of shoots plant⁻¹ was highest (3.63 plant⁻¹) with the application of 150 kg N ha⁻¹ as reported by Gupta and Pal (1989).

Kushwah (1989) observed that average plant height increased from 44.4 to 51.5 cm with the increase in N dose from 120 to 150 kg ha⁻¹.

Sharma and Upadhyay (1993) reported that plants receiving sufficient N were characterized by vigorous plant growth, increased leaf area index and large tuber size and number.

Singh and Sood (1996) observed that plant height and number of stems plants⁻¹ were favorably influenced by N levels upto 120- 180 kg ha⁻¹.

Singh (2000) reported that plant emergence was not affected due to manuring or good management practices.

Brache *et al*, (2000) observed tallest plant height (69.4 cm) in potato cultivar Kufri Jyoti with 175.5; 125 and 125 kg ha⁻¹ N, P and K, respectively.

Singh and Raghav (2000) while studying response of potato to nitrogen and potassium fertilizers, reported that cultivar Kufri Jyoti showed maximum height (55.1 cm) at 160 kg N ha⁻¹.

2.1.2 Effect of nitrogen on tuber yield and yield attributes.

According to Gupta (1969) application of 150 kg N ha⁻¹ increased the tuber yield significantly as compared to the control. Increase in the level of nitrogen resulted in significant increase in ware grade tubers of K-12 Z variety at 150 kg N-ha⁻¹.

Singh and Singh (1970) while studying the effect of there levels of nitrogen 100, 150 & 200 kg ha⁻¹ and irrigation on two varieties

viz. K- Shakti and K- Sindhuri, observed that the tuber yield was highest at 200 kg N ha⁻¹ level.

Sagar and Singh (1973) reported that bulking rate with 100 kg N ha⁻¹ was as good as with 150 kg N ha⁻¹.

Sah and Sahay (1974) reported that N application at 120-kg ha⁻¹ increased the yield of tubers by increasing tuber number and their weight. Mandal and Arora (1975) observed that number of tubers hill⁻¹ was mostly a varietal character however, the successive increment in nitrogen significantly affected the number of tubers hill⁻¹.

Gupta and Saxena (1975) reported that significant increase in tuber yield was recorded at 180-kg N ha⁻¹ accompanied by a dose of 52.5 kg P₂O₅ ha⁻¹.

Singh and Grewal (1979) reported highest tuber yield with 100 kg N ha⁻¹ + 83 kg K ha⁻¹.

Sahota and Perumal (1986) observed that progressive increase in tuber yield was recorded with every increase in the level of N upto 80 kg ha⁻¹ similar results have been reported by Grewal *et al*, (1979) and Sahota and Grewal (1979).

Singh *et al*, (1986) reported that application of 120 kg N and 80 kg K ha⁻¹ alongwith 2 kg Agromin ha⁻¹ to Kufri Badshah, Kufri Bahar and Kufri Sinduri gave a tuber yield of 26.3, 16.3 and 15.2 tonnes ha⁻¹, respectively.

Singh and Sharma (1987) studied the response of potato cv. Kufri Jyoti and two hybrids to different levels of nitrogen application (0 to 180 kg ha⁻¹) and observed that increase in the levels increase the average tuber yields from 10.21 to 22.03 t ha⁻¹.

Studies conducted by Sharma and Shekhar (1989), on split application of nitrogen on the yield of potato cv. Kufri Chandramukhi reported that higher tuber yield of 29.03 t ha⁻¹ was obtained with the application of 50 per cent nitrogen at planting and 25 per cent 4 weeks after emergence. This treatment also recorded higher proportion of medium sized tubers (50 to 100g) and the lower proportion of the smaller tubers (50 g).

Anand and Krishnappa (1989) reported that the highest tuber yield of 26.08 t ha⁻¹ was obtained with the application of 180-kg N and 150kg K ha⁻¹.

Gupta and Pal (1989) while studying the response of potato cultivars viz ev SLB 12-132,” Kufri Jyoti” and Kufri Sherpa” to nitrogen fertilization under rainfed condition, recorded the highest yields of 42.71, 34.38 and 18.90 t ha⁻¹ with the application of 50, 100 and 150 kg N ha⁻¹, respectively.

Kushwah (1989) found that the highest tuber yield of 25.5 and 20.3 t ha⁻¹ were recorded with 100 kg N ha⁻¹ in a two year study, respectively significant increase in yield was observed only upto 150 kg N ha⁻¹.

Mondy and Munshi (1989) reported the highest tuber yield at 150 kg N ha⁻¹.

Sharma and Arora (1990) reported that tuber yield in cv. Kufri Chandramukhi increased with the application of N upto 150 kg ha⁻¹ at 45 DAP and 200 kg N ha⁻¹ at later stages.

Sharma (1990) observed that increase in tuber yield at 120 kg N ha⁻¹ was due to increase in the weight of large and medium sized tubers.

Nandekar *et al*, (1991) while studying the fertilizer requirements of Kufri Badshah variety, observed that tuber yield increased upto 120 kg N, 50 kg P₂O₅ and 50 kg K₂O ha⁻¹ application. Sharma and Grewal (1991) observed that tuber yield increased with the application of N, P and K upto 120: 20: 80 kg ha⁻¹, respectively.

Sud *et al*, (1991) reported that higher levels of N application delayed tuber initiation in early stages and the abundant availability of N in the soil was more effectively utilized in pushing up vegetative growth.

Sharma and Upadhyay (1993) observed that plants supplied with sufficient nitrogen produced large sized and more number of tubers.

Das and Banerjee (1994) reported the maximum tuber weight with the application of 160: 100: 100 kg N, P and K ha⁻¹, respectively.

Sharma *et al*, (1995) reported the highest tuber yield (25.36 t ha⁻¹) in cv. JH- 222 with the application of nitrogen at 160 kg ha⁻¹.

Chaurasia and Singh (1996) reported that the highest net return was obtained when nitrogen was applied at 180 kg ha⁻¹ and the haulmus were cut on 120 DAP.

Roy (1996) found that application of 240 kg N and 50 kg P₂O₅ ha⁻¹ gave tuber yield of 45.6 t ha⁻¹ and also the highest net returns.

Singh and Sood (1996) observed that N application at 60, 120 and 180 kg ha⁻¹ produced a tuber yield of, 21.1, 26.1 and 28.4 t ha⁻¹, respectively as compared to 13.4 t ha⁻¹ without N application. (Control).

Meena and Gupta (1996) observed the highest tuber yield of 16.2 t ha⁻¹ and high returns with the application of 120 kg N ha⁻¹.

Singh and Verma (1998) reported the highest tuber yield of 12.8 t ha⁻¹ in the cv. "PC 189" with the application of 150: 90: 100 kg N, P and K ha⁻¹, respectively along with FYM.

Singh *et al*, (1998) observed that potato tuber yields increased with increasing N rate (100, 150, 200 or 250 kg N ha⁻¹) and seed tuber size.

Singh (2000) reported highest tuber yield with the application of 100: 120: 50 kg of N: P₂O₅: K₂O, respectively alongwith 15 tonnes of FYM ha⁻¹.

Brache *et al*, (2000) while studying the response of potato to fertility levels and plant growth regulators in black cotton soils, obtained largest tubers in potato cv. Kufri Jyoti with the application of 175.5: 125: 125 kg N: P: K ha⁻¹, respectively and planting small sized tubers with the application of 150: 100: 100 kg N: P: K ha⁻¹, respectively.

Hassandokht and Kashi (2000) reported the highest mean tuber weight, dry matter content, protein and starch and tuber yield of 18.99 and 24.85 t ha⁻¹ in cvs. Aula and Moren with the application of 160 kg N ha⁻¹.

Singh and Raghav (2000) while studying the response of potato to nitrogen and potassium fertilization under U. P. Tarai conditions recorded the tuber yield of 254.0 q ha⁻¹ at 160 kg N ha⁻¹ application in cv. Kufri Ashoka.

Sharma and Dubey (2000) reported the highest values for tubers hill⁻¹ (7.0) in cv. Chandramukhi with the application of 150 kg N ha⁻¹ and lowest values for tubers hill⁻¹ (3.0) with 75 kg N ha⁻¹.

Lanker *et al*, (2000) observed that significant increase in tuber yield (238.33 to 290 q ha⁻¹) was obtained with the increase in the application of nitrogen from 80- 160 kg ha⁻¹.

2.1.3 Effect of nitrogen on tuber grades

Effect of nitrogen on the size of tubers has been studied by several research workers. Das and Ghosh (1973) observed that N application in general stimulated the initiation of more tubers of bigger size.

Mandal and Arora (1975) reported that higher levels of nitrogen significantly increased the ware size tubers and decreased the seed and chat sized tubers. Similar findings have been reported by Kapoor (1952) and Hukkeri (1968).

Shukla and Singh (1975) observed that application of 225: 150: 240 kg ha⁻¹ N, P and K, respectively produced more number of 'A' grade tubers.

Satyanarayana and Arora (1985) reported that nitrogen had significant effect on the tuber size of 'A' and 'B' grade.

Chadchan *et al*, (1986) observed significant increase in different tuber grades with the increase in nitrogen application (100- 200 kg ha⁻¹).

Sharma and Arora (1987) reported that nitrogen application decreased the number of small sized tubers but increased the number of large sized ones.

Anand and Krishnappa, (1988) observed that nitrogen application significantly increased the weight of A, B and C grade tubers as

compared to control and higher levels of N application of 180 kg ha^{-1} alongwith 150 kg K ha^{-1} gave higher yield of 'A' grade tubers and decrease in N levels decreased the tuber size. Similar findings have been reported by Singh and Grewal (1984) and Khurana *et al*, (1984). Sharma and Shekhar (1989) observed that application of N at 100 kg ha^{-1} at emergence increased the proportion of tubers of less than 50 g weight. Kushwah (1989) observed significant increase in the number of seed size tubers at 150 kg N ha^{-1} . Sharma and Sharma (1990) reported that N increased the number as well as size of tubers.

Sharma (1990) reported that tuber yield increased with nitrogen application due to increase in the weight of large and medium sized tubers.

Das and Banerjee (1994) observed the highest percentage of large size tubers ($> 45\text{mm}$) at the application of the highest fertility level of 160: 100: 100 NPK kg ha^{-1} .

Singh (1995) observed that the highest dose of 200 kg N ha^{-1} effectively increased the 'A' and 'B' grade tubers and there was minimum production of 'C' grade tubers.

Roy and Sharma (1999) observed increase in yield and number of large, sized tubers when N, P and K was increased to 150 percent of the recommended dose of 180: 28: 100 kg ha^{-1} N: P: K, respectively.

Brache *et al*, (2000) reported that in potato cultivar "Kufri Jyoti" large size tubers were obtained with the application of 175.5: 125: 125 kg ha^{-1} N: P: K as compared to the application of 150: 100: 100 kg ha^{-1} N: P: K that yielded small sized tubers, respectively

2.4 Effect of nitrogen on dry matter production.

The findings of different workers are presented as follows.

Hukkeri (1968) reported that N had little effect on dry matter content of tubers.

Yadav (1970) stated that application of nitrogen (100 and 200 kg ha⁻¹) in sandy loam soil under draught conditions showed an adverse effect on starch and dry matter content.

Mandal and Arora (1975) reported that fresh weight of tubers hill⁻¹ increased with nitrogen application upto 150 kg ha⁻¹ and in later stages the fresh tuber weight was higher with higher dose of N applied. Similar findings were reported by Ram *et al*, (1979).

Shukla and Singh (1976) observed that higher doses of N, P and K @ 225, 150 and 210 kg ha⁻¹, respectively, produced the highest dry matter.

Singh (1977) in a field experiment on potato revealed significant increase in tuber yield, dry matter and protein production ha⁻¹ with the increase in the level of FYM application, where as application of 200 kg nitrogen ha⁻¹ showed harmful effects in all the above trials in comparison to 100 kg N ha⁻¹.

Sud *et al*, (1982) reported that nitrogen fertilization exerted a highly significant influence on the dry matter and protein yield of tubers in both the cutlivars viz. “Kufri Chandramukhi” and “Kufri Jyoti”. The response of potato in terms of dry matter yield were significantly marked upto 50 kg N ha⁻¹. Whereas, increase in dose of nitrogen above 150 kg ha⁻¹ depressed the dry yield of tubers.

Mishra and Singh (1983) reported marked increase in bulking rate, dry matter of tubers, tuberization efficiency and tuber yield at 180 kg N ha⁻¹.

Hari and Hooda (1987) observed maximum dry matter accumulation (tuber and whole plant) at the highest fertility level of 187 kg N ha⁻¹.

Castro (1988) observed that application of N upto 125 kg ha⁻¹ significantly increased reducing sugars in tubers in cv. “Kennbec and Desiree”. He further stated that potash significantly reduced dry matter content.

Krishnappa (1989) reported that fertilizer application almost doubled the dry matter production in Potato crop.

Beirne and Cassidy (1990) observed that tuber dry matter content was significantly reduced by the application of more than 150 kg N ha⁻¹.

Hassandokht and Kashi (2000) observed that mean tuber weight, dry matter, protein and starch content were highest with 160 kg N ha⁻¹ in potato cultivars “Aula and Moren”.

Patel *et al*, (2000) reported highest dry weight of shoots and tubers plant⁻¹ with the application of 260 kg N ha⁻¹ in “Kufri Badash”.

2.5 Effect Of Nitrogen on C:B ratio

Lanker (1999) obtained the highest cost benefit ratio with the application of 160 kg N ha⁻¹ in potato cv. Kufri Jyoti. Similar results were reported by Singh (1998).

2.6 Effect of phosphorus on plant growth

Application of phosphorus before planting has neither positive nor negative effect on crop emergence, but it increases root and shoot

growth of the plant. The increase in root growth by P application has been reported by De (1960) and Pushkernath (1976).

Pushkernath *et al*, (1976) reported that application of P increased the plant height by 20 percent. Sharma *et al*, (1981) reported that the application of P increased the plant height by 60 percent.

Sharma and Singh (1988) observed significant increase in plant height upto the application of 120 kg P₂O₅ ha⁻¹.

Joseph (1988) while studying the effect of P on growth and yield of potato, observed that there was no significant difference in germination percentage in different treatments, but plant height increased when P level was increased from 0 to 180 kg ha⁻¹.

Nandekar *et al*, (1991) observed that plant emergence was not significantly affected by varying levels of N: P: K application. However, the N, P and K application increased the number of shoots from 5.3 to 7.3 plant⁻¹ as compared to control. Similar results have been obtained by Sharma and Singh (1988).

Hossain *et al*, (1997) reported increased leaf number, leaf length, leaf area and stem number with the application of 75 kg P₂O₅ ha⁻¹. Brache *et al*, (2000) observed the tallest plant height of 69.4 cm in cv. “K. Jyoti” with the application of 175:125:125 of N: P: K, kg ha⁻¹, respectively.

Singh *et al*, (2001) observed significant increase in plant height and weight of foliage hill⁻¹ with increasing phosphorus levels.

2.7 Effect of Phosphorus on tuber growth

Shukla and Singh (1975) reported that N: P: K application at 225:150:240 kg ha⁻¹ gave higher tuber bulking rate. P increased the

number as well as weight of tubers (Sharma *et al*, 1976). Similar results have been obtained by Sharma *et al*, (1984). Application of nitrogen and phosphorus has been reported to increase size and number of tubers, Sharma *et al*, (1985).

Joseph (1988) while studying the effect of phosphorus on growth and yield of potato, observed that tuber number increased as the level of P was increased from 0-180 kg ha⁻¹. He also found that average tuber weight did not increase above 140 kg P ha⁻¹ level.

Sharma and Singh (1988) reported a significant increase in number of tubers m⁻² with the application of 120 kg P₂O₅ ha⁻¹.

Lal and Arora (1994) observed P application (0-90 kg ha⁻¹) improved the bulking rate, tuber number and tuber yield over the control at all growth stages.

Deka and Dutta (1996) found that the tuber-bulking rate was highest at 100 kg P₂O₅ ha⁻¹ application.

Hossian *et al* (1997) reported that the application of P at 75 kg ha⁻¹ increased the mean tuber weight in potato cv. “patrones”.

2.8 Effect of Phosphorus on Yield.

Hukkeri (1968) reported that yield of potato increased with increase in the level of fertilizers and this increase was upto 90 kg P₂O₅ ha⁻¹.

Shukla and Singh (1975) observed that maximum yield of potato was produced with the application of 225: 150: 240 of N, P and K ha⁻¹, respectively.

Gupta and Saxena (1975) found that significant increase in tuber yield at higher levels of N was obtained only when it was accompanied by a dose of 52.5 kg P₂O₅ ha⁻¹.

Shukla and Singh (1976) while studying the response of different levels of nitrogen in combination with 80 kg P₂O₅ and 60 kg K₂O ha⁻¹, observed increase in the tuber yield to 27.9 tonnes ha⁻¹ with the highest dose of N applied.

Deroncele and Valdes (1978) reported that application of 200 kg N, 100 kg P₂O₅ and 200 kg K₂O ha⁻¹ to potato cv. "Red Potaic" increased the yield to 20.28 tonnes ha⁻¹, as compared to control (9.03 t ha⁻¹).

Kurlekar and Pawar (1978) observed that application of 80 kg of N along with 100 kg phosphorus and potash ha⁻¹ gave the highest tuber yield of 26.46 t ha⁻¹ as compared to 16.93 t ha⁻¹ in the control.

Madhikarmy (1978) reported that application of 25 t FYM + 180 kg N + 100 kg P₂O₅ + 100 kg K₂O ha⁻¹ gave the highest average tuber yield of 15.96 t ha⁻¹ in cv. "Kufri Jyoti"

Krishnappa and Gowda (1979) recorded maximum tuber yield (222.2 q ha⁻¹) at 180, 50 and 50 kg N, P and K ha⁻¹ application, respectively. Similar results are reported by Khurana *et al*, (1977).

Trehan *et al*, (1982) reported that application of 100 kg ha⁻¹ each of N, P₂O₅ and K₂O increased tuber yield significantly.

Verma and Grewal (1983) observed that potato tuber yield increased linearly by increasing the rates of N, P and K ha⁻¹ from 0-120 kg ha⁻¹ and the optimum economic rates were 115, 120 and 90 kg ha⁻¹, respectively.

Trehan and Grewal (1984) observed that balanced application of NPK fertilizers (150 kg N + 40 kg P₂O₅ + 80 kg K₂O ha⁻¹) gave significantly higher yield of tubers (376.4 q ha⁻¹).

Singh *et al*, (1986) reported that application 120 kg nitrogen, 80 kg phosphorus, 80 kg potash and 2 kg agromin ha⁻¹ gave tuber yield of 26.3, 16.3 and 15.3 t ha⁻¹ in potato cultivars “Kufri Badshah”, “Kufri Bahar” and “Kufri Sindhuri”, respectively.

Sharma and Singh (1988) while studying response of potato to N, P and K, reported significant increase in potato tuber yield upto the application of 120 kg N, 180 kg P₂O₅ and 60 kg K₂O ha⁻¹.

Jaggi *et al*, (1988) while studying the response of potato to fertilizer application, concluded that potato cv. “Kufri Jyoti” markedly responded to the application of 150, 52.5 and 75 kg N, P and K ha⁻¹, respectively.

Joseph (1988) reported that optimum yield of tubers (492 q ha⁻¹) was obtained with the application of 100 kg P₂O₅ ha⁻¹.

Sharma and Sharma (1989) observed that application of 100, 44 and 42 kg N, P and K ha⁻¹, respectively to the “Kufri chandramukhi” recorded the highest average tuber yield of 50.87 t ha⁻¹ as compared to the control.

Nazaryuk and Prozorov (1989) recorded a tuber yield of 29.1 t ha⁻¹ with the application of 120, 60 and 100 kg N, P and K ha⁻¹, respectively.

Shanmugavelu (1989) reported that application of nitrogen at 180 kg ha⁻¹ alongwith 50 kg P₂O₅ and K₂O ha⁻¹ gave a maximum yield of 222.29 q ha⁻¹ as compared to other combinations.

Krishnappa (1989) while studying the effect of different levels of P and their methods of application to potato in sandy loam soil, reported that increase in P level upto 50 kg ha⁻¹ increased the tuber yields significantly.

Sharma and Grewal (1991) while studying the response of potato to NPK fertilization and their interaction effects, observed significant yield response to nutrients with balanced use of N P and K. They also recorded an optimum economic dose of 143, 43 and 89 kg ha⁻¹ of N, P and K, respectively. Similar results were reported by Benepal (1967). Nandekar *et al*, (1991) while studying the fertilizer requirements of cv."K.Badshah" observed that application of N, P and K upto 120 kg N, 50 kg P₂O₅ and 50 kg K₂O ha⁻¹ respectively increased the tuber yield' significantly. Sharma and Grewal (1991) observed increase in the tuber yields with the application of N, P and K upto 120,20 and 80 kg ha⁻¹, respectively. Lal and Arora (1993) while studying the response of potato cultivars to Phosphatic and Potassic fertilizers observed that all potato cultivars under test were equally responsive to P fertilization and tuber yield increased significantly upto 45 kg P₂O₅. Similar response to P fertilizer was observed by Upadhyay and Grewal (1985). Lal and Arora (1994) reported that application of p upto 90 kg ha⁻¹ gave the highest tuber yield of 263.0 q ha⁻¹.

Minhas *et al*, (1994) observed that the direct P application upto 78 kg P₂O₅ ha⁻¹ to spring crop and 52 kg P₂O₅ kg ha⁻¹ to autumn crop increased the potato yield significantly.

Deka and Dutta (1996) in field trial on sandy loam acidic soil found that cv. K. Jyoti gave highest tuber yields with the application of 100 kg P₂O₅ ha⁻¹.

Roy (1996) found that application of 240 kg N and 50 kg P₂O₅ ha⁻¹ gave tuber yield of 45.6 t ha⁻¹ with highest net returns.

Singh *et al*, (1996) reported that tuber yield was highest with application of 15 t FYM in combination with 100 kg P₂O₅.

Hossain *et al*, (1997) observed that the application of 75 kg P₂O₅ ha⁻¹ was optimum and increased tuber yield in the potato cv.”Patrones”.

Alvarez *et al*, (1999) reported that application of 207 kg P₂O₅ ha⁻¹ gave the highest tuber yield (18 t ha⁻¹) in cv “ Meriquense”.

Roy and Sharma (1999) observed significant increase in the yield and number of large sized tubers when the NPK application was raised to 150 per cent of the recommended dose of 180,28 and 100 kg of N, P and K, respectively.

Singh and Sharma (2002) reported that phosphorus exerted significant effect on tuber yields at 120 kg P₂O₅ ha⁻¹.

2.2.3 Effect of Phosphorus on tuber grades and dry matter content

Hukkeri (1968) while studying effects of nitrogen, phosphorus and potash on yield and quality of potato, reported that application of phosphorus upto 90 kg ha⁻¹ resulted in the increase of seed sized tubers without affecting the percentage dry matter content of tubers.

Shukla and Singh (1975) observed that higher proportion of ‘A’ grade tubers were produced with the fertilizer dose of 225: 150: 240 kg N, P and K ha⁻¹, respectively.

Application of nitrogen and phosphorus was also reported to increase the size and number of potato tubers (Dubetz and Bole, 1975).

Shukla and Singh (1976) also reported higher proportion of 'A' grade tuber even with the application of 150 kg N, 80 kg P₂O₅ and 180 kg K₂O ha⁻¹ and also reported that application of 225 kg N + 150 kg P₂O₅ + 240 kg K₂O ha⁻¹ produced the highest dry matter in tubers.

Negi *et al.*, (1982) recorded the highest yield of large sized tubers (45.41 q ha⁻¹) with the application of 120, 40 and 80 kg N,P and K ha⁻¹, respectively. He further, reported that the tuber yield increased due to increase in the tuber size.

Mishra and Singh (1983) observed that application of 193.67 kg N and 93.6 kg P₂O₅ ha⁻¹ was more profitable and gave marked increase in the bulking rate, dry matter accumulation of tubers and tuber yield.

Singh *et al.*, (1984) reported that phosphorus application upto 80 kg P₂O₅ ha⁻¹ improved dry matter of tubers significantly. Similar results have been reported by Sharma *et al.* (1981).

Reddy *et al.*, (1986) While studying effect of different doses of P and K on growth and tuber yield of potato cv. "Kufri Deva", "Kufri chandramukhi" and "Kufri Bahar", observed that application of both P and K increased significantly proportion of 'A' grade tubers and dry matter of tubers. This increase was highest in "Kufri Deva" as compared to other cultivars. Similar results have been reported by Grewal and Trehan (1979).

Hari and Hooda (1987) recorded maximum tuber dry matter production in the cv. "Kufri Chandermukhi" at the highest fertility level. (187.5 kg N + 37.9 kg P₂O₅ + 75.0 kg K₂O ha⁻¹).

Sharma and Arora (1987) reported that application of P decreased the number of large and medium sized tubers but increased the number

of small sized tubers. Whereas Krishnappa (1989) reported that application of phosphorus increased the yield of large and medium sized tubers and had no significant effect on small sized tubers. Similar results have been reported by Sharma *et al*, (1976) and Verma and Grewal (1978).

Lal and Arora (1993) observed that P application upto 90 kg ha⁻¹ increased the leaf area index, stems, leaves and total dry matter and finally the yield.

Das and Banerjee (1994) experienced the highest percentage of large tubers (> 45 mm) and average tuber weight with the highest fertility level of 160:100:100 kg ha⁻¹ N, P and K, respectively.

Deka And Dutta (1996) in a field trial found that in cv. Kufri Jyoti the yield of small tubers > 25 g was unaffected with the application of P, whereas the yield of medium (25-75 g) and large (<75 g) tubers were highest with the application of 100 kg P₂O₅ ha⁻¹.

Brache *et al*, (2000) observed that higher proportion of large sized tubers were obtained in the Potato cv. “Kufri Jyoti” with the application of 175.5:125:125 kg of N:P:K kg ha⁻¹, respectively, whereas application of 150:100:100 kg N:P:K ha⁻¹ yielded higher proportion of small sized tubers.

Singh *et al*, (2001) reported that the maximum weight of tubers of different grades were recorded with 150 kg P ha⁻¹.

2.2.4 Effect of Phosphorus on Benefit-Cost ratio.

Singh *et al*, (2001) obtained the highest benefit cost ratio with the application of 100 kg P₂O₅ for HPS 1/13.

CHAPTER- III

MATERIALS AND METHODS

The materials used and the techniques followed during the course of present investigation are described in this chapter.

3.1 location

The present investigation was conducted at the experimental farm of Division of Olericulture, Sher-e-Kashmir University of Agricultural Sciences and Technology, Shalimar Campus, Srinagar Kashmir during Kharif- 2002. The location is situated at an elevation of 1587 m above sea level between 34.1 North latitude and 74.89 East longitude. The topography of the land is flat.

3.2 Agro- meteorological features of the experimental site.

The climate of the Kashmir valley is humid temperate characterized by hot summers and severe winters. The average annual rainfall is 944.6 mm (ranging from 676 to 1193 mm). More than eighty percent of the rainfall is received from December to April. Winters are very cold and cloudy followed by hot sunny summer months. The temperature ranges between 0.80C⁰ to 33.0C⁰.

The meteorological data for the cropping period recorded at meteorological observatory, Division of Agronomy, S. K. University of Agricultural Sciences and Technology of Kashmir Shalimar is presented in Appendix-1.

The minimum and maximum temperature recorded during the cropping season was 4.7- 17.1 and 15.5- 31.4, respectively.

The total rainfall received during the entire cropping season was 113.68 mm.

3.3 Physical and chemical characteristics of soil.

Representative soil samples were taken randomly from the experimental fields. These samples were dried, ground and sieved for mechanical and chemical analysis prior to sowing operation. The soil of the experimental field was silty clay loam in texture with low in available nitrogen and medium in available phosphorus and potassium. The soil had a neutral pH, normal EC and high organic carbon content. The results of the analysis are presented in Table-1.

Table 1: - Physical and chemical characteristics of the soil of the experimental site.

Soil properties: -

A. MECHANICAL ANALYSIS

<u>Component</u>	<u>Percent</u>	<u>Method employed</u>
i). Coarse sand	1.5	International pipette method (Piper 1966)
ii) Fine sand	18.3	
iii) Silt	42.8	
iv) Clay	36.8	
v) Texture	silty clay loam	The texture and class of soil was determined using textural diagram

B. CHEMICAL ANALYSIS

<u>Component</u>	<u>Value</u>	<u>Method employed</u>
i) Electric conductivity (dsm^{-1})	0.30	1: 2 soil water suspension with solubility conductivity meter (Jackson, 1973).
ii) pH	6.9	1: 2: 5 soil water suspension using pH meter (Jackson, 1973).
iii) Organic carbon (%)	0.87	Wet digestion method (Walkey and Black, 1934) Rapid titration method suggested by Piper, 1966).
iv) Available N (kg ha^{-1})	256	Modified alkaline permanganate method (Subbiah and Asija, 1956).
v) Available P (kg ha^{-1})	15.6	Extraction with 0.5 M NaHCO_3 (Olsen <i>et al</i> , 1954) using systronics spectrophotometer
vi) Available K (kg ha^{-1})	263	Extraction with neutral normal NH_4OAC using systronics flamephotometer (Marwin and Peech, 1950).
vii) Cation exchange capacity (ml kg ha^{-1})	11.35	Ammonium acetate extraction method (Chapman, 1973).

3.5 Experimental details

Treatments comprised of three potato cultivars, three levels of nitrogen and three levels of phosphorus. The design adopted was split

plot with three replications. The varieties were planted in main plot and the fertilizers put in subplots.

3.5.1 Treatment details

A. Main plots

a). 3 cultivars

i). PP- 2500

ii). PP- 48

iii). Kufri Jyoti

B. Subplots

b). 3 nitrogen levels

$$N_1 = 120 \text{ kg ha}^{-1}$$

$$N_2 = 160 \text{ kg ha}^{-1}$$

$$N_3 = 200 \text{ kg ha}^{-1}$$

c). 3 phosphorus levels

$$P_1 = 80 \text{ kg ha}^{-1}$$

$$P_2 = 100 \text{ kg ha}^{-1}$$

$$P_3 = 120 \text{ kg ha}^{-1}$$

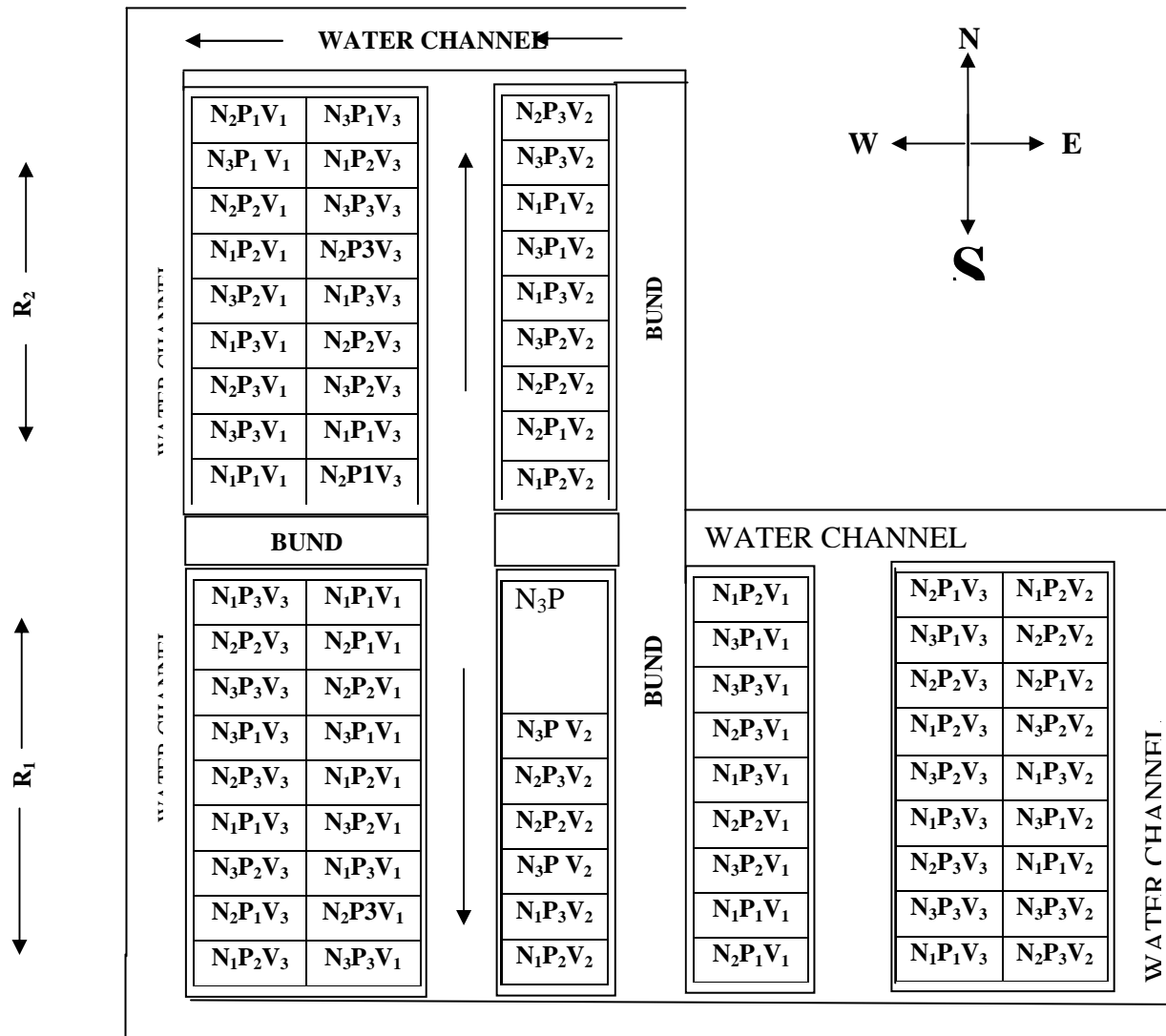
(Potash was applied as per package of practices @ 100 kg K₂O ha⁻¹)

Replication : 3

Plot size : 3.0 x 2.0 m²

Spacing : 60 cm x 20 m

Experiment was laid out in split plot design as per Fig- 1.



3.5.2 Treatment combinations

$N_1P_1V_1$

$N_1P_2V_1$

$N_1P_3V_1$

$N_2P_1V_1$

$N_2P_2V_1$

$N_2P_3V_1$

$N_3P_1V_1$

$N_3P_2V_1$

$N_3P_3V_1$

$N_1P_1V_2$

$N_1P_2V_2$

$N_1P_3V_2$

$N_2P_1V_2$

$N_2P_2V_2$

$N_2P_3V_2$

$N_3P_1V_2$

$N_3P_2V_2$

$N_3P_3V_2$

$N_1P_1V_3$

$N_1P_2V_3$

$N_1P_3V_3$

$N_2P_1V_3$

$N_2P_2V_3$

$N_2P_3V_3$

$N_3P_1V_3$

$N_3P_2V_3$

$N_3P_3V_3$

3.6 Agronomic operations

The cultural practices carried out during the crop season are described as under: -

The experimental plot was ploughed with a tractor twice, followed by leveling and planking to get a fine tilth. Weeds and trashes were removed and the field was laid out as per the layout plan.

The main plot was assigned to varieties and the sub plot to the fertilizers. The fertilizers were applied to each plot at random. Full dose of P and K was applied as basal dose. Half of nitrogen was given at planting time and the remaining half at the time of first earthing up. Quantity of N supplied by DAP was also accounted for calculation of N dose.

The fertilizers were applied in the following commercial form.

(I) Urea 46% N

- (ii) DAP 18% N and 46% P₂O₅
- (iii) MOP 60% K₂O

3.6.1 *Plant materials used*

Healthy tubers of cultivar PP-2500, PP-48 and Kufri Jyoti were obtained from research station Pahalgam. The tubers with signs of bruises, disease infestation etc were rejected. The tubers having more than two eyes were selected and planted on well-prepared ridges in the main plots assigned to each variety separately. A spacing of 60 cm. Ridge to ridge and 20 cm, plant to plant was followed. There were five rows in each sub plot and ten tubers in each row. The planting was done on 20th of March 2002.

The experimental field was irrigated twice at an interval of 25 days.

3.6.2 *Earthing up of the crop*

The earthing up of the crop was done twice. The first hoeing and earthing was done after one month of planting and the second fifteen days later.

3.6.3 *Weeding*

Besides hoeing of the crop, two hand weedings were also followed to remove all the weeds before they would have assumed a critical stage.

3.6.4 Plant protection

The crop was sprayed with Mancozeb at 0.2% concentration and Dichlorovos 0.5% twice to control any possible attack of diseases (late and early blight) and insects and pests.

3.6.5 Details of other cultural operations.

The details of various other fields operations performed during the cropping season are presented in the Table 2.

Table 2: - Details of cultural operations

Nature of the operation	Date
Ploughing	12- 3-2002
Clod breaking and leveling	15- 3-2002
Layout, raising of bunds and making of irrigation channels	17- 3-2002
Weighment and application of fertilizers (basal dose).	19- 3-2002
Planting of potato tubers	20-3-2002
Ist hoeing and application of ½ N (Top dose)	19-4-2002
First irrigation	1- 5-2002
Second hoeing	5-5-2002
Second irrigation	25-5-2002
Dehaulming	19-7-2002
Harvesting of the crop	29-7-2002

3.6.6. *Dehaulming*

Dehaulming of the crop was done 10 days before harvesting.

3.7 *Harvesting*

Harvesting of the dehaulmed crop was done by digging out potato tubers manually from the experimental plots separately for each treatment combination variety wise and replication wise. The harvested crop was allowed to dry to a desired moisture content before weighing and grading.

3.8 *Observations recorded*

3.8.1 *Sampling techniques for growth and yield component traits.*

Ten representative plants were selected from each of the experimental plot at random and tagged with labels for periodical recording of data for different parameters. The results obtained were expressed as average (mean) of ten plants.

3.8.1.1 *Percent emergence*

Plant emergence count was taken thrice at an interval of 10 days from the emergence of the first tuber above soil. For emergence count the data was recorded variety wise for the each treatment. The mean was worked out and subjected to statistical analysis.

3.8.1.2 *Plant height (cm)*

The height of the main shoot of each tagged plant was recorded from the ground level to the tip of the main shoot. The recording was repeated thrice during the cropping season and the mean was worked out.

3.8.1.3 Number of shoots plant⁻¹

The number of shoots plant⁻¹ were recorded in the tagged plants thrice during the crop season and the number plant⁻¹ at the final observation was analyzed.

3.9. Yield

Before harvesting the experimental plots. The border rows were harvested first and all the precautions taken. The potatoes were cleaned off from soil and were kept in properly labeled trays plot wise for weighing and grading. The plot wise yield was calculated and converted into q ha⁻¹.

3.9.1 Tuber number plant⁻¹

At harvest ten plants selected randomly were dug out separately from each treatment plot and the number of tubers plant⁻¹ was counted and the average worked out.

3.9.2 Average tuber weight

Average tuber weight was calculated at the time of harvesting from ten randomly selected plants from each treatment plot by dividing the weight of tubers by tuber number and then the average of ten plants was worked out for analysis. Similarly average tuber weight plant⁻¹ was also worked out by dividing weight of tubers by number of plants.

3.9.3 Grading of potato tubers

At harvest, the tubers from each treatment were graded variety wise and replication wise in the following categories.

“A” grade (large size) tubers above 50 g sorted, weighed and calculated kg plant^{-1} .

“B” grade (medium size) tubers (25- 50 g) sorted, weighed and calculated kg plant^{-1} .

“C” grade (small size) tubers ($< 25\text{g}$) weighed and calculated kg plant^{-1} .

3.10 Dry matter percentage

Estimation of dry matter was done from fresh material. 100 g of potato tubers was taken from each treatment. It was sliced and oven dried at 60C^0 till constant weight.

3.11 Benefit-Cost ratio.

Gross returns were worked out by multiplying yield obtained with the market price. The cost of cultivation was subtracted from the gross returns and results obtained were presented in rupees ha^{-1} .

3.12 Statistical analysis

The statistical analysis for each parameter was carried out on mean values. The data was subjected to analysis of variance as per the INDOSTAT software package.

CHAPTER- IV

EXPERIMENTAL RESULTS

The Research Findings of the experiment laid out to assess the response of potato cultivars to varying levels of nitrogen and phosphorus fertilization are described in detail in this chapter.

4.1. Influence on the morphological traits.

4.1.1 Percent emergence.

Analysis of variance (Appendix-II) revealed that the main effect of different varieties was significant where as that of nitrogen and phosphorus was non-significant on plant emergence. The interaction effects resulting from variety x nitrogen, variety x phosphorus, nitrogen x phosphorus and variety x nitrogen x phosphorus were non- significant.

Varieties revealed significant differences for their ability of plant emergence (Table-3). The variety PP-48 had the highest plant emergence (94.30%) followed by PP-2500 (93.50%) and Kufri Jyoti (90.70%). The varieties PP-48 and PP-2500 showed significant difference for per cent emergence as compared to Kufri Jyoti whereas there was no

significant difference between the emergence percentage of PP-48 and PP-2500. Application of different levels of nitrogen and phosphorus had non-significant effect on percent emergence. The increase in percent emergence with the increase in levels of nitrogen and phosphorus was non-significant.

4.1.2. Plant height.

Perusal of analysis of variance (Appendix-II) revealed that all the main factors viz. cultivars, different levels of nitrogen and phosphorus had significant effect on plant height.

Table 3: - Effect of different levels of Nitrogen and Phosphorus on the percent emergence in Potato cultivars.

<i>Treatments</i>		<i>Percent emergence</i>
Cultivars		
<i>PP-2500</i>		93.50
<i>PP-48</i>		94.30
<i>Kufri Jyoti</i>		90.70
<i>SE (d)</i>		1.29
<i>CD(5%)</i>		2.59
Nitrogen levels(kg ha⁻¹)		
<i>N₁</i>	120	92.30
<i>N₂</i>	160	92.37
<i>N₃</i>	200	93.18
<i>SE(d)</i>		1.28
<i>CD at 5%</i>		N.S
Phosphorus levels(kg ha⁻¹)		
<i>P₁</i>	80	92.00
<i>P₂</i>	100	92.50

P_3	120	93.10
$SE(d)$		1.19
$CD (5\%)$		N.S

Plant height (Table-4) was significantly higher in PP-48 (56.52cm) as compared to PP-2500 (51.99 cm) and Kufri Jyoti (50.31 cm). Nitrogen application increased the plant height significantly, as the dose increased. At 120 kg N ha⁻¹ the plant height was 50.88 cm, which increased to 52.97 cm at 160 kg N ha⁻¹ and to 54.97 cm at 200 kg N ha⁻¹. Similarly, application of different levels of phosphorus increased the plant height linearly; at 80 kg P ha⁻¹, the plant height was 52.58 cm, which increased to 53.05 cm and 53.19 cm at 100 and 120 kg P ha⁻¹ respectively. However the increase was non-significant only between 100 and 120 kg P ha⁻¹ as compared to 80 kg P ha⁻¹.

Interaction resulting from variety x different levels of nitrogen was significant and it was observed that plant height increased significantly when the dose of nitrogen was raised from 120 to 200 kg ha⁻¹ in all the three cultivars.

Interaction resulting from variety x phosphorus, nitrogen x phosphorus and variety x nitrogen x phosphorus were non-significant.

4.1.3. Number of shoots plant⁻¹

Number of shoots plant⁻¹ revealed a significant variance (Appendix-II) for varieties and different levels of nitrogen application.

Maximum shoots plant⁻¹ (4.77) (Table-5) were observed in PP-48 which was significantly higher as compared to both PP-2500 (4.62) and Kufri Jyoti (3.95). Application of nitrogen increased number of shoot plant⁻¹ linearly and significantly as the dose increased from 120 to 200 kg N ha⁻¹. At 120 kg N ha⁻¹ the shoot number was 4.20 which increased significantly to 4.59 at 160 kg N ha⁻¹ but thereafter the increase was non significant being 4.73 shoots plant⁻¹ at 200 kg N ha⁻¹.

Table 4: - Effect of different levels of nitrogen and phosphorus on Plant height in Potato cultivars.

Treatments	Plant height (cm)
Cultivars	
<i>PP-2500</i>	51.99
<i>PP-48</i>	56.52
<i>Kufri Jyoti</i>	50.31

SE(d) 0.14
C.D(5%) 0.41

Nitrogen levels (kg ha⁻¹)

*N*₁ 120 50.88
*N*₂ 160 52.97
*N*₃ 200 54.97
SE(d) 0.12
CD(5%) 0.26

Phosphorus levels (kg ha⁻¹)

*P*₁ 80 52.58
*P*₂ 100 53.05
*P*₃ 120 53.19
SE(d) 0.19
CD(5%) 0.40

Interaction effect of cultivars and nitrogen

Cultivars	Nitrogen levels (kg ha ⁻¹)		
	120	160	200
PP-2500	49.71	51.70	54.57
PP-48	54.43	56.75	58.40
Kufri Jyoti	48.52	50.47	51.94

SE (d) 0.21
CD (5%) 0.46

Table 5: - Effect of different levels of nitrogen and phosphorus on number of shoots plant⁻¹ in potato cultivars.

Treatments		No. of shoots plant ⁻¹
Cultivars		
<i>PP-2500</i>		4.62
<i>PP-48</i>		4.77
<i>Kufri Jyoti</i>		3.95
<i>SE(d)</i>		0.22
<i>CD(5%)</i>		0.63
Nitrogen levels (kg ha⁻¹)		
<i>N₁</i>	120	4.20

N_2	160	4.59
N_3	200	4.73
$SE(d)$		0.16
$CD(5\%)$		0.36

Phosphorus levels (kg ha⁻¹)

P_1	80	4.26
P_2	100	4.34
P_3	120	4.42
$SE(d)$		0.14
$CD(5\%)$		N.S

The main effects of phosphorus and all the interaction effects were found non-significant.

4.2. Yield and yield parameters

Yield parameters consisted tuber number plant⁻¹ and average tuber weight where as tuber yield was estimated as quintals ha⁻¹.

4.2.1. Tuber number plant⁻¹

Analysis of variance (Appendix-III) revealed a significant difference between varieties, different levels of nitrogen phosphorus application and interaction of nitrogen with varieties and phosphorus. The interaction among varieties x nitrogen x phosphorus and the interaction between variety & phosphorus was non-significant.

Maximum tuber number plant⁻¹ (Table-6) was observed in PP-48 (11.79) followed by PP-2500 (11.40) & Kufri Jyoti (10.13). The difference in the mean performance of all the three varieties was significant. The cultivars PP-2500 and PP-48 were statistically at par with each other in respect of tuber number plant⁻¹ but both these cultivars differed significantly from Kufri Jyoti. Application of nitrogen had a significant increase from 10.44 tubers plant⁻¹ at 120 kg N ha⁻¹ to 11.95 tubers plant⁻¹ at 160 kg N ha⁻¹ but a significant decrease to 10.77 tubers plant⁻¹ was observed when the dose was increased to 200 kg N ha⁻¹. In case of application of different levels of phosphorus almost a similar trend was

observed. The tuber number of 10.82 plant⁻¹ recorded with the application of 80 kg P ha⁻¹ increased significantly to 11.48 tubers plant⁻¹ with 100 kg P ha⁻¹ but decreased significantly to 10.86 tubers plant⁻¹ with the application of 120 kg P ha⁻¹.

Interaction resulting from the varieties and nitrogen revealed that a significant increase occurred with the application of 120 to 160 kg N ha⁻¹.

Table 6: - Effect of different levels of nitrogen and phosphorus on tuber number plant⁻¹ in potato cultivars.

<i>Treatment</i>	<i>Tuber number plant⁻¹</i>	
	Cultivars	
<i>PP-2500</i>		11.40
<i>PP-48</i>		11.79
	<i>Kufri Jyoti</i>	10.13
<i>SE (d)</i>		0.20
<i>CD (5%)</i>		0.57
Nitrogen Level (kg ha⁻¹)		
<i>N₁</i>	120	10.44
<i>N₂</i>	160	11.95
<i>N₃</i>	200	10.77
<i>SE (d)</i>		0.15

CD (5%) 0.34

Phosphorus Level (kg ha⁻¹)

<i>P</i> ₁	80	10.82
<i>P</i> ₂	100	11.48
<i>P</i> ₃	120	10.86

***SE (d)* 0.15**

CD (5%) 0.31

Interaction effect of cultivars and nitrogen

Cultivars	Nitrogen levels (kg ha ⁻¹)		
	120	160	200
PP-2500	10.40	12.06	11.40
PP-48	11.40	12.66	11.32
Kufri Jyoti	9.31	11.11	9.53

SE (d) 0.27
CD (5%) 0.60

Interaction effect of nitrogen and phosphorus

Nitrogen levels kg ha ⁻¹	phosphorus levels (kg ha ⁻¹)		
	80	100	120
120	9.88	10.48	10.73
160	11.31	12.86	11.66
200	11.20	10.85	10.20

SE (d) 0.26
CD (5%) 0.54

But the tuber number decreased significantly as the dose was increased to 200 kg N ha⁻¹ in all the three cultivars. In case of interaction between nitrogen and phosphorus, it was observed that a linear and significant increase occurred with increase in the application of phosphorus levels in combination with 160 kg N ha⁻¹. But at 200 kg N ha⁻¹ a linear and significant decrease was observed as the dose of P increased from 80- 120 kg ha⁻¹. However, in case of 160 kg N ha⁻¹, there was significant increase in tuber number when phosphorus level increased from 80- 100 kg ha⁻¹ but at 120 kg P ha⁻¹ a significant decrease was observed.

4.2.2 Average tuber weight (g) and tuber weight plant⁻¹.

Analysis of variances (Appendix-III) revealed that main effect of cultivars and different levels of nitrogen, and phosphorus, and interaction resulting from application of nitrogen with variety and phosphorus were significant. The interaction between variety x phosphorus and variety x nitrogen x phosphorus were non- significant.

The average tuber weight was maximum in PP-48 (42.05g) (Table-7) followed by PP-2500 (41.24g) and Kufri Jyoti (39.17g). These differences among the cultivars were highly significant. Application of different levels of nitrogen had a significant effect on the average tuber weight. The tuber weight of 40.36g recorded with the application of 120kg N ha⁻¹ increased significantly to 42.40g with the application of 160kg N ha⁻¹, but at 200kg N ha⁻¹, it significantly decreased to 39.71g.

Application of different levels of phosphorus showed a significant effect on tuber weight. The tuber weight of 40.80 g recorded at

Table 7: - Effect of different levels of nitrogen and phosphorus on average tuber weight in potato cultivars.

Treatments	Average tuber weight (g)
Cultivars	
<i>PP-2500</i>	41.24
<i>PP-48</i>	42.05

<i>Kufri Jyoti</i>	39.17
<i>SE (d)</i>	0.12
<i>CD (5%)</i>	0.36

Nitrogen levels (kg ha⁻¹)

<i>N₁</i>	120	40.36
<i>N₂</i>	160	42.40
<i>N₃</i>	200	39.71
<i>SE (d)</i>		0.16
<i>CD (5%)</i>		0.34

Phosphorus levels (kg ha⁻¹)

<i>P₁</i>	80	40.80
<i>P₂</i>	100	41.29
<i>P₃</i>	120	40.57
<i>SE (d)</i>		0.22
<i>CD (5%)</i>		0.46

Interaction effect of cultivar and nitrogen

Cultivars	Nitrogen levels (kg ha ⁻¹)		
	120	160	200
PP-2500	40.96	42.23	40.53
PP-48	41.96	44.60	39.60

Interaction effect of nitrogen and phosphorus

Nitrogen levels kg ha ⁻¹	phosphorus levels (kg ha ⁻¹)		
	80	100	120
120	40.00	40.17	40.93
160	41.76	43.33	42.10
200	40.63	39.80	38.70

Kufri	38.17	40.36	39.00
Jyoti			

SE (d) 0.27

CD(5%) 0.60

80kg P₂O₅ ha⁻¹ increased significantly to 41.29g at 100kg P₂O₅ ha⁻¹. But at 120kg P₂O₅ ha⁻¹ it significantly decreased to 40.57 g.

Interaction of application of different levels of nitrogen in the potato cultivars revealed that in general a significant increase was observed when the nitrogen dose increased from 120 to 160kg ha⁻¹. But at 200kg N ha⁻¹ a significant decrease was observed in all the three cultivars. Interaction arising between the application of different levels of nitrogen and phosphorus, revealed that at 120kg N ha⁻¹ application, a linear increase was observed as the P level increased from 80-120kg ha⁻¹, but the difference was significant only between the highest and the lowest dose of phosphorus. At 160 kg N ha⁻¹ applied, a significant increase was observed as the dose increased from 80-100kg P ha⁻¹. But at 120kg P ha⁻¹ it revealed a significant decrease in tuber weight. At 200kg N ha⁻¹ there was a gradual decrease as the dose of P increased from 80-120kg ha⁻¹ and this decrease was significant at each level.

Similarly tuber weight plant⁻¹ was maximum in PP-48 (0.396 kg) (Table-8) followed by PP-2500 (0.375 kg) and Kufri Jyoti (0.348 kg). These differences among the cultivars were significant.

The interaction effect of cultivar x nitrogen revealed a similar trend as observed in case of average tuber weight. The interaction arising between application of different levels of nitrogen and phosphorus revealed that at 120kg N ha⁻¹ a significant increase was observed as the level of P was raised from 80-100kg ha⁻¹ but a significant decrease was observed at 120 kg P ha⁻¹. At 160kg N ha⁻¹ applied, a significant increase was observed as dose increased from 80-100kg P ha⁻¹. But at 200kg N ha⁻¹

Table 8: - Effect of different levels of nitrogen and phosphorus on tuber weight plant-1 in potato cultivars.

Treatments	Tuber weight (kg plant⁻¹)
Cultivars	
<i>PP-2500</i>	0.375
<i>PP-48</i>	0.396
<i>Kufri Jyoti</i>	0.348
<i>SE (d)</i>	0.003
<i>CD (5%)</i>	0.010
Nitrogen Levels (kg ha⁻¹)	
<i>N₁</i> 120	0.349

N_2	160	0.410
N_3	200	0.360
$SE(d)$		0.001
$CD(5\%)$		0.003

Phosphorus Levels (kg ha⁻¹)

P_1	80	0.372
P_2	100	0.384
P_3	120	0.363
$SE(d)$		0.002
$CD(5\%)$		0.005

Interaction effect of cultivars and nitrogen

Cultivars	Nitrogen levels (kg ha ⁻¹)		
	120	160	200
PP-2500	0.352	0.418	0.335
PP-48	0.359	0.435	0.394
Kufri Jyoti	0.336	0.376	0.331

SE (d) 0.002
CD (5%) 0.005

Interaction effect of nitrogen and phosphorus

Nitrogen levels kg ha ⁻¹	phosphorus levels (kg ha ⁻¹)		
	80	100	120
120	0.345	0.358	0.344
160	0.395	0.425	0.410
200	0.378	0.368	0.334

SE (d) 0.004
CD (5%) 0.008

there was a significant decrease as the dose of P increased from 80-120kg ha⁻¹.

4.2.3. Total yield (q ha⁻¹)

This is the most important economic parameter in the potato crop. Analysis of variance (Appendix-III) revealed that all the factors i.e., cultivars, nitrogen & phosphorus applications and interactions resulting from these factors were significant except the interaction between variety x phosphorus and variety x nitrogen x phosphorus.

Performance of different cultivars of potato revealed that (Table-9) PP-48 produced the highest tuber yield of (303.28 q ha⁻¹) followed by PP-2500 (281.73 q ha⁻¹) followed by Kufri Jyoti (261.51q ha⁻¹).

Application of nitrogen significantly increased the tuber yield from 264.86 quintals ha⁻¹ recorded with the application of 120kg N ha⁻¹ to 314.26 q ha⁻¹ quintals ha⁻¹ recorded with the application of 160kg N ha⁻¹, which however, decreased significantly to 269.39 quintals ha⁻¹ as the dose increased to 200kg N ha⁻¹. Similarly application of phosphorus increased the tuber yield from 280.81 quintals ha⁻¹ recorded with the application of 80kg P ha⁻¹ to 290.78 quintals ha⁻¹ when the dose was increased to 100 kg P ha⁻¹ but again at the highest dose of 120 kg P ha⁻¹ tuber yield decreased to 274.93 quintals ha⁻¹.

Interaction resulting from the application of different levels of nitrogen in the potato cultivars revealed almost a similar trend i.e. the tuber yield increased significantly when the dose was increased from 120 to 160kg N ha⁻¹ but it

decreased significantly as the dose further increased to 200kg N ha⁻¹ in all the three cultivars. In case of nitrogen x phosphorus interaction, it was observed that a significant increase resulted when phosphorus applications increased from 80–100kg P ha⁻¹ at both 120 and

Table 9: - Effect of different levels of nitrogen and phosphorus on tuber yield in potato cultivars.

Treatments		Tuber yield (q ha ⁻¹)
Cultivars		
	<i>PP-2500</i>	281.73
	<i>PP-48</i>	303.28
	<i>Kufri Jyoti</i>	261.51
	<i>SE (d)</i>	7.04
	<i>CD (5%)</i>	15.68
Nitrogen Levels (kg ha⁻¹)		
	<i>N₁</i> 120	264.86
	<i>N₂</i> 160	314.26
	<i>N₃</i> 200	269.39
	<i>SE (d)</i>	8.53
	<i>CD (5%)</i>	17.69
Phosphorus Levels (kg ha⁻¹)		
	<i>P₁</i> 80	280.81

P_2	100	290.78
P_3	120	274.93
$SE(d)$		3.37
$CD(5\%)$		6.84

Interaction effect of cultivar and nitrogen

Cultivars	Nitrogen levels (kg ha ⁻¹)		
	120	160	200
PP-2500	260.99	313.41	270.90
PP-48	282.02	340.63	287.21
Kufri Jyoti	251.80	289.24	245.21

SE (d) 6.11
CD (5%) 13.32

Interaction effect of nitrogen and phosphorus

Nitrogen levels kg ha ⁻¹	phosphorus levels (kg ha ⁻¹)		
	80	100	120
120	258.91	273.20	260.69
160	299.16	328.63	315.49
200	284.85	270.51	247.95

SE (d) 5.84
CD (5%) 11.85

160kg N ha⁻¹ but at 120kg P ha⁻¹ a significant decrease was observed in the tuber yield at both the levels of nitrogen. However in case of 200 kg N ha⁻¹ a linear and significant decrease was observed as the dose of P increased from 80–120 kg P ha⁻¹.

4.3 Tuber grades

Quality of tubers in terms of different grades is having economic importance from both the points of view of seed potatoes and table purpose potatoes.

4.3.1 “A” grade tubers

Tubers weighing more than 50g were graded as ‘A’ and the yield of such tubers in kg plant^{-1} was worked out.

Analysis of variance (appendix-IV) revealed highly significant difference for all the main factors, cultivars, nitrogen and phosphorus and the interaction arising from variety x nitrogen. All other interactions were non-significant.

Maximum ‘A’ grade tubers (Table-10) were observed in cultivar PP-48 ($0.197 \text{ kg plant}^{-1}$) followed by PP-2500 ($0.172 \text{ kg plant}^{-1}$) and Kufri Jyoti ($0.171 \text{ kg plant}^{-1}$). However the difference was significant only when the cultivar PP-48 was compared with the other two cultivars. Application of nitrogen increased the ‘A’ grade tuber yield from $0.182 \text{ kg plant}^{-1}$ recorded with the application of 120 kg N ha^{-1} to $0.193 \text{ kg plant}^{-1}$ at 160 kg N ha^{-1} . But at the higher level of 200 kg N ha^{-1} it decreased significantly to $0.170 \text{ kg plant}^{-1}$. Similarly with the application of different levels of phosphorus the ‘A’ grade tuber yield of $0.169 \text{ kg plant}^{-1}$ recorded at $80 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ increased to $0.195 \text{ kg plant}^{-1}$ at $100 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ but decreased significantly to $0.182 \text{ kg plant}^{-1}$ at $120 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$.

Table 10: - Effect of nitrogen and phosphorus on tuber yield in

grades plant⁻¹ in potato cultivars.

Treatments **Tuber yield in grades (kg plant⁻¹)**

Cultivars	<i>A</i>	<i>B</i>	<i>C</i>
<i>PP-2500</i>	0.172	0.123	0.081
<i>PP-48</i>	0.197	0.135	0.082
<i>Kufri Jyoti</i>	0.171	0.122	0.076
<i>SE (d)</i>	0.002	0.001	0.025
<i>CD (5%)</i>	0.008	0.003	NS

Nitrogen Levels (kg ha⁻¹)

<i>N₁</i>	120	0.182	0.127	0.074
<i>N₂</i>	160	0.193	0.128	0.074
<i>N₃</i>	200	0.170	0.126	0.092
<i>SE (d)</i>		0.004	0.001	0.024
<i>CD (5%)</i>		0.008	N.S	N.S

Phosphorus Levels (kg ha⁻¹)

<i>P₁</i>	80	0.169	0.119	0.072
<i>P₂</i>	100	0.195	0.133	0.081
<i>P₃</i>	120	0.182	0.134	0.087
<i>SE (d)</i>		0.003	0.001	0.024
<i>CD (5%)</i>		0.006	0.002	N.S

**Interaction effect of cultivars and nitrogen
(Grade 'B')**

Cultivars	Nitrogen levels (kg ha⁻¹)		
	120	160	200
PP-2500	0.117	0.128	0.123
PP-48	0.133	0.139	0.134

**Interaction effect of cultivars and nitrogen
(Grade 'A')**

Cultivars	Nitrogen levels (kg ha ⁻¹)		
	120	160	200
PP-2500	0.175	0.181	0.160
PP-48	0.196	0.210	0.185
Kufri Jyoti	0.170	0.176	0.167

SE (d) 0.006

CD (5%) 0.015

Interaction effects resulting from application of different levels of nitrogen and different cultivars revealed a significant increase in the tuber yield of 'A' grade tubers which increased when nitrogen levels were raised from 120-160kg ha⁻¹. But it significantly decreased as the dose was further increased to 200kg N ha⁻¹.

4.3.2 "B" grade tubers

'B' grade tubers were categorized as the ones having tuber weight of 25 to 50gm. Analysis of variance (appendix-IV) revealed that only the main effects of cultivars, different levels of phosphorus and interaction arising from cultivar x nitrogen were significant. The other effects were non- significant.

The highest 'B' grade tuber yield of 0.135kg plant⁻¹ was observed in PP- 48 (Table-10) followed by PP- 2500 (0.123kg plant⁻¹) and Kufri Jyoti (0.122kg plant⁻¹) and this difference of PP-48 as compared to other two cultivars was significant. Application of different levels of nitrogen did not increase the yield of 'B' grade tubers significantly but application of different levels of phosphorus revealed that the 'B' grade tuber yield increased significantly from 0.119kg plant⁻¹ at 80kg P₂O₅ ha⁻¹ to 0.134 kg plant⁻¹ at 100kg P₂O₅ ha⁻¹ but thereafter it increased non significantly to 0.34 kg plant⁻¹ with the application of 120 kg P₂O₅ ha⁻¹ in all the three cultivars.

The interaction effect of cultivar x nitrogen revealed a significant increase when the level of nitrogen was increased from 120 to 160kg ha⁻¹ but it decreased significantly when the dose was increased further to 200kg N ha⁻¹.

4.3.3 "C" grade tubers

Tubers weighing less than 25g were graded as 'C'. Perusal of analysis of variance (Appendix-IV) revealed that none of the main factors (Table 10) or the interaction among them was significant and hence the variation in the values has arisen exclusively because of sampling error and need not be highlighted.

4.4 Dry matter percentage

Dry matter accumulation in plants is a photosynthetic and nutrient assimilation and utilization efficiency measurement. In the present study dry matter (%) was estimated in tubers.

Analysis of variance (Appendix-IV) revealed that all the main factors viz., cultivars, application of nitrogen & phosphorus and interaction arising from cultivars, Nitrogen and phosphorus were significant.

Potato cultivars revealed an inherent property of difference in dry matter content. Maximum dry matter content (20.03%) was observed in PP-48 (Table-11) followed by PP-2500 (19.76%) and Kufri Jyoti (19.00%). The differences were significant in all the three cultivars. Application of different levels of nitrogen revealed that maximum and significant increase in dry matter percentage was observed with the application of 160kg N ha⁻¹ (20.14%) as compared to (18.81%) recorded with the application of 120 kg N ha⁻¹ but at 200 kg N ha⁻¹ a non-significant decrease was observed. Similarly with the application of phosphorus a significant increase in the dry matter content of tuber was observed at 100kg P ha⁻¹ (19.99%) as compared to dry matter content (19.32%) recorded with the application 80kg P ha⁻¹. In this case also at higher level of 120kg P ha⁻¹ the dry matter content decreased significantly to 19.68%.

Table 11: - Effect of different levels of nitrogen and phosphorus on dry matter percentage in potato cultivars.

Treatments		Dry matter percentage
Cultivars		
<i>PP-2500</i>		19.76
<i>PP-48</i>		20.03
<i>Kufri Jyoti</i>		19.00
<i>SE (d)</i>		0.09
<i>CD (5%)</i>		0.26
Nitrogen Levels (kg ha⁻¹)		
<i>N₁</i>	120	18.81
<i>N₂</i>	160	20.14
<i>N₃</i>	200	20.04
<i>SE (d)</i>		0.05

CD (5%) 0.11

Phosphorus Levels (kg ha⁻¹)

*P*₁ 80 19.32

*P*₂ 100 19.99

*P*₃ 120 19.68

SE (d) 0.06

CD (5%) 0.13

CHAPTER- V

DISCUSSION

The potato (*Solanum tuberosum* L.) is one of the four most important crops of the world, the other three being rice, wheat and maize. A short duration crop like potato, which is nutritionally superior and capable of producing high amount of food per unit area and time, has a great potential in modern agriculture for meeting the increasing food requirements of the country. Therefore in a country like India with a large population to feed, potato is perhaps one of the best answers to meet the growing food needs. But this can be realized only if due attention is paid to the effective utilization of environment and inputs by adopting cultural practices on a scientific basis.

Potato can be grown only under such situations where the temperatures during growing season are moderately cool. However it can grow and give economic returns under any climate provided the night temperatures during tuberization remain around 20⁰C. (Shekawat *et al*, 1999).

Geographical location, length of growing season, fertility status of soil, soil type, varieties and other environmental factors play a significant role in the growth and successful cultivation of potato together with the significant influence of nutritional application (Sharma *et al*. 1978, Chaurasia and Singh 1993).

Potato crop is sensitive to nutrient stress owing to its shallow and sparse root system N, P and K needs of the crop vary with the soil type and its nutrient supplying capacity, variety, cropping system and sources of nutrients. Research studies on mineral fertilizer application and varietal responses have been conducted for several decades and they continue to be the focus of research even today. Although a lot of information has been gained on these aspects, the need for determination of optimum fertilizer standards for potato cultivars continues to be important. The present study was thus conducted to ascertain the response of potato cultivars to varying levels of nitrogen and phosphorus fertilization.

The results thus obtained have been made to interpret important findings in light of available literature.

5.1 Growth parameters

5.1.1 *Percent emergence*

Plant emergence was taken regularly at an interval of 10 days from the emergence of the first tuber and continued for 30 days after planting.

Cultivars showed significant differences for their ability to emergence. The cultivar PP-48 showed the highest plant emergence (94.30%) followed by PP-2500 (93.50%) and Kufri Jyoti (90.70%). Our findings are in close conformity to those of Gagro *et al*, (2000). However our findings are quite contrast to those of Ram *et al*, (1979) who observed that cultivars did not exhibited significant differences with respect to emergence. The differences in observations may be due to peculiar agroclimatic conditions which prevailed during the present studies.

The plant emergence was not significantly influenced by increasing levels of nitrogen. The results are in concurrence with the findings of Mandal and Arora (1975), Singh (1995), Nandekar *et al*, (1991) and Singh (2000).

The plant emergence was not significantly influenced by increasing levels of phosphorus. These findings are in line with those of Joseph (1988) and Nandekar *et al*, (1991). Krishnappa (1989), Pushkarnath (1976) Verma and Grewal (1978).

5.1.2 Plant height

Cultivars exhibited significant differences in plant height. Cultivar PP-48 produced the tallest plants (56.52 cm) as compared to PP-2500 (51.99cm) and Kufri Jyoti (50.31cm). These results are in agreement with the findings of Sahota and Perumal (1986) and Nandekar *et al*, (1994).

The plant height was significantly influenced by nitrogen application, as shortest plant height (50.88cm) was recorded at 120 kg N ha⁻¹ while the tallest height (54.97cm) at 200 kg N ha⁻¹. Similar results have been reported by Sah and Sahay (1974), Mandal and Arora (1975), Singh *et al*, (1986), Kushwah (1989), Singh and Sood (1996) and Singh and Raghav (2000). This increase in plant height might be due to the fact that higher nitrogen concentration stimulated the assimilation of carbohydrates and protein, which in turn enhanced cell division and formation of more tissues that resulted in enhanced vegetative growth of the plant. (Mayer and Anderson, 1970).

Similarly application of varying levels of phosphorus increased the plant height linearly and significantly. The plant height was 52.58cm at 80 kg P ha⁻¹ and was recorded 53.19cm at 120 kg P ha⁻¹. Similar findings have been

reported by Pushkernath (1976), Joseph (1988) and Singh *et al*, (2001). The interaction between cultivars and nitrogen produced a significant effect on plant height. It may be due to the fact that nitrogen plays an important role in promoting vegetative growth and plants with sufficient nitrogen are characterized by vigorous plant growth (Sharma and Upadhyay, 1993).

5.1.3 Number of shoots plant⁻¹

Potato cultivars showed significant difference in number of shoots plant⁻¹. Maximum number of shoots plant⁻¹ (4.77) were observed in cultivar PP-48 which was significantly higher as compared to cv. PP-2500 (4.62) and Kufri Jyoti (3.95). Similar results have been reported by Sahota and Perumal (1986) and Nandekar *et al*, (1994).

Application of nitrogen increased number of shoots plant⁻¹ linearly from 120 to 200 kg N ha⁻¹ which increased non significantly to 4.59 at 160 kg N ha⁻¹, but when the level of nitrogen was increased to 200 kg ha⁻¹ the number of shoots plant⁻¹, increased significantly to 4.73. These findings are confirmed by Mandal and Arora (1975), Satyanaryana and Arora (1985), Gupta and Paul (1989) and Singh and Sood (1996).

Number of shoots plant⁻¹ increased non significantly when the level of phosphorus was raised from 80 to 120 kg P₂O₅ ha⁻¹. Similar findings have been reported by Sharma and Singh (1988) and Nandekar *et al.* (1991).

5.2 Yield and yield parameters

5.2.1 Tuber number plant⁻¹

Cultivars exhibited significant differences in relation to tuber number plant⁻¹. Maximum tuber number plant (11.79) was observed in cv. PP-48 followed by cv. PP-2500 (11.40) and Kufri Jyoti (10.13). The difference in the mean performance of all the three cultivars was significant. Similar findings have been reported by Sahota and Perumal (1986), Reddy *et al.* (1986), Sharma and Verma (1987) and Kushwah *et al.* (1993).

Number of tubers per plant increased significantly from (10.44 to 11.95) with the increase in level of nitrogen from 120 to 160 kg N ha⁻¹ and when the level of nitrogen was increased to 200 kg ha⁻¹ tuber number plant⁻¹ decreased significantly to 10.77 tuber plant⁻¹. The reduction in tuber number was due to the fact that plant growing under high nitrogen availability had significantly higher rate of carbohydrate accumulation in the leaves but the rate at which the carbohydrates were exported from leaves was significantly lower in the high nitrogen treatment suggesting low tuber sink strength. Our findings are in line with those reported by Mandal and

Arora (1975), Reddy and Rao (1968), Satyanaryana and Arora (1985), Kushwah (1989) and Sharma and Dubey (2000).

Tuber number plant⁻¹ increased significantly with the increase in phosphorus levels upto 100 kg P₂O₅ ha⁻¹. It was recorded 10.82 at 80 kg P ha⁻¹ and 11.48 at 100 kg P₂O₅ but when the phosphorus level was further raised to 120 kg ha⁻¹ the tuber number decreased significantly to 10.86. Similar results have been reported by Sharma *et al*, (1984) and Lal and Arora (1994).

The interaction between cultivars and nitrogen and nitrogen and phosphorus exhibited significant effect on tuber number plant⁻¹. Maximum tuber number of 12.86 tubers plant⁻¹ was obtained due to the combined effect of nitrogen and phosphorus at 160 kg and 100 kg ha⁻¹, respectively. This may be attributed to various physiological activities within the plant resulting in increased tuber number. Increase in tuber number plant⁻¹ may be due to increased photosynthetic activity and translocation of photosynthates to the roots that might have helped in the initiation of more stolons (Anand and Krishnappa, 1989).

5.2.2 Average tuber weight (g)

Significant differences in average tuber weight was observed with respect to potato cultivars. Average tuber weight was maximum (42.05g) in cv. PP-48 followed by cv. PP-2500 (41.24g) and Kufri Jyoti (39.17g). Similarly the tuber weight plant⁻¹ was observed maximum (0.390 kg

plant⁻¹) in cv. PP-48 followed by cv. PP-2500 (0.375 kg plant⁻¹) and 0.348 kg plant⁻¹ in Kufri Jyoti. These differences in tuber weight among cultivars have been reported by Sahota and Perumal (1986), Reddy *et al*, (1986), Sharma and Verma (1987), Kushwah *et al*, (1993) and Nandekar *et al*, (1994).

Significant increase in average tuber weight was observed when nitrogen level was increased from 120 to 160 kg N ha⁻¹. At 120 kg N ha⁻¹ it was recorded 40.36g and at 160 kg N ha⁻¹ 42.40g. but when the level of nitrogen was further increased to 200 kg N ha⁻¹ a significant reduction in tuber weight was observed. Similar trend was observed in tuber weight plant⁻¹, which increased significantly upto 160 kg N ha⁻¹ after which a significant reduction was observed at 200 kg N ha⁻¹. Similar results have been reported by Das and Banerjee (1994) and Hassandokth and Kashi (2000). The decrease in tuber weight at higher levels of nitrogen could be an adverse effect of luxuriant vegetative growth at higher nitrogen availability. Excessive amount of nitrogen delays tuber initiation and tuber growth (Sharma and Upadhyay, 1993.)

Similarly average tuber weight increased significantly when the level of phosphorus was raised to 100 kg ha⁻¹. The average tuber weight of 40.80 g was recorded at 80 kg P₂O₅ ha⁻¹ which increased significantly to 41.10g at 100 kg P₂O₅ ha⁻¹. But further increase in the level of phosphorus to 120 kg P ha⁻¹ caused a reduction in tuber weight to 40.57g. A similar trend of significant

increase in tuber weight plant⁻¹ upto 100 kg P₂O₅ ha⁻¹ and a significant decrease at 120 kg P₂O₅ was also observed. Similar findings have been reported by Sharma *et al*, (1976), Sharma *et al*, (1984) and Das and Banerjee (1994). The interactions between cultivars and nitrogen showed significant effect on tuber weight. The combined effect of nitrogen and phosphorus levels 160 kg ha⁻¹ and 100 kg ha⁻¹, respectively. With respect to tuber weight showed significant superiority over the other treatment combinations in all the cultivars.

5.2.3 Tuber yield (q ha⁻¹)

The cultivars differed significantly in their yield potential. The highest tuber yield (303.289 q ha⁻¹) was obtained from cv. PP-48 which was significantly higher than other cultivars cv. PP-2500 recorded a yield of 281.73 q ha⁻¹ which was significantly higher than 261.51 q ha⁻¹ recorded in Kufri Jyoti. Our findings are in confirmation with those reported by Sagar and Singh (1973), Shukla and Singh (1975), Shukla *et al*, (1985), Reddy *et al*, (1986), Kushwah *et al*, (1989), Govindakrishna *et al*. (1991), Mondy and Munshi (1991), Sud *et al*, (1991), Chadchen *et al*, (1993), Nanderkar *et al*, (1994), Randhwa and Kooner (1994), Lal and Arora (1994), Ghosh (1995) and Swamy and Krishnappa (1995) and Patel *et al*, (2002).

Significant increase in yield with respect to different levels of nitrogen was found upto 160 kg N ha⁻¹, but a significant reduction in yield was observed at 200 kg N ha⁻¹.

At 120 kg N ha⁻¹ a tuber yield of 264.86 q ha⁻¹ was recorded which increased significantly to 314.26 q ha⁻¹ at 160 kg N ha⁻¹. Thereafter the tuber yield reduced significantly to 269.39 q ha⁻¹ at the higher dose of 200 kg N ha⁻¹.

The higher yield was due to better vegetative growth, resulting in assimilation of more carbohydrates and their translocation to the tubers, which ultimately help in enlargement of tuber size and weight. (Shukla and Singh, 1976). However, since tuber yield is a complex character and is the net result of many physiological processes, it cannot possibly be related to a single parameter alone. (Shekhawat *et al*, 1999).

Our findings are in conformity with those reported by Mondy and Munshi (1989), Trehan *et al*, (1982), Nandekar *et al*, (1991), Sud *et al*, (1991), Govindakrishnan (1991), Sharma *et al*, (1995), Lanker *et al*, (2000), Singh and Raghav (2000), Hassandokht and Kashi (2000).

Effect of phosphorus application on tuber yield in the present study revealed that tuber yield increased significantly with the increase in phosphorus levels upto 100 kg P₂O ha⁻¹ and a significant decrease in tuber yield was observed at 120 kg P₂O₅ ha⁻¹. At 80kg P₂O₅ ha⁻¹ the tuber yield recorded was 280.91 q ha⁻¹. Which increased significantly to 290.78 q ha⁻¹ at 100 kg P₂O₅ ha⁻¹. Thereafter a significant reduction to 274.93 q ha⁻¹ was observed at 120 kg P₂O₅ ha⁻¹. The highest yield was

obtained at 100 kg P₂O₅ ha⁻¹. Similar results have been reported by Kurlekar and Pawar (1978), Madhikarmy (1978), Trehan *et al*, (1982), Joseph (1988), Sharma (1991), Deka and Dutta (1996), Singh *et al*, (1996). The interaction between cultivar and nitrogen showed significant effect with respect to tuber yield.

The interaction between nitrogen and phosphorus showed a significant response for yield ha⁻¹. The application of 160 kg N in combination with 100 kg P₂O₅ ha⁻¹ showed a remarkable increase in yield (328.63 q ha⁻¹). This increase might be due to more synthesis of chlorophyll, and protein and diversion of metabolites towards growth and development of tubers which was observed maximum at 160 kg N and 100 kg P₂O₅ ha⁻¹.

5.3 Tuber yield in grades

5.3.1 Grade 'A' (above 50g)

Tubers weighing > 50 g were graded as 'A' and the yield of such tubers kg plant⁻¹ was worked out. Maximum 'A' grade tubers were obtained in CV. PP-48 followed by CV. PP-2500 and Kufri Jyoti, however the difference was significant only when CV.PP-48 was compared with other two cultivars.

The difference in production of 'A' grade tubers by different cultivars have been reported by Chadchan *et al*, (1986), Reddy *et al*, (1986), Shukla and Singh(1975), Gupta and Pal (1989), Swamy and Krishnappa(1995) and Singh *et al*, (2001).

The highest yield of 'A' grade tubers plant⁻¹ was observed at 160 kg N ha⁻¹, but at 200 kg N ha⁻¹ a significant reduction was observed. Similar findings were reported by Hukkeri (1968), Singh and Grewal (1984), Khurana *et al.*, (1984), Satynaryana and Arora (1985), Anand and Krishnappa (1988), Das and Banerjee (1986) and Lanker (1999).

The effect of phosphorus on production of 'A' grade tubers revealed that the highest yield of 'A' grade tubers was obtained at 100 kg P₂O₅ ha⁻¹ and thereafter a significant reduction was observed at 120 kg P₂O₅ ha⁻¹. Our findings are in close conformity to those reported by Krishnappa (1989), Das and Banerjee (1994) and Deka and Dutta (1996). The interaction between cultivars and different levels of nitrogen produced significant effect on production of 'A' grade tubers. This may be due to the fact that nitrogen in general resulted in better vegetative growth, enhanced the assimilation of carbohydrates and metabolites and their translocation to the tubers which resulted in large size of tubers.

5.3.2. Grade 'B' (25 to 50 g)

The potato cultivars differed significantly in the production of 'B' grade tubers. Maximum 'B' grade tubers were observed in cv. PP-48 followed by cv. PP-2500 and Kufri Jyoti. cv. PP-48 differed significantly from the other two cultivars in the production of 'B' grade tubers while as cv. PP-2500 and Kufri Jyoti were at par with each other, thus confirming the findings

reported by Skukla and Singh(1975), Reddy *et al*, (1986), Gupta and Pal ((1989), Trehan and Grewal(1991), Kushwah *et al*, (1993) and Swamy and Krishnappa(1995).

Increase in level of nitrogen increased the 'B' grade tuber production upto 160 kg N ha⁻¹ but this increase was non-significant. Similar results have been reported by Hukkeri (1968),Mandal and Arora(1975), Satyanaryana and Arora(1985) and Kushwah(1989).

Increase in the levels of phosphorus significantly increased the yield of 'B' grade tubers .The highest yield of 'B' grade tubers was obtained at 100 kg P₂O₅ ha⁻¹ and after that a non-significant decrease was observed at 120 kg P₂O₅ ha⁻¹. Similar findings have been reported by Krishnappa (1989) and Deka & Dutta (1996). The interaction between cultivars and nitrogen with respect to production of 'B' grade tubers exhibited significant effect.

5.3.3 Grade 'C' (Below 25 g)

No significant difference among the cultivars in production of 'C' grade tuber was observed. However, maximum yield of 'C' grade tubers was observed in cv. PP-48 followed by PP-2500 and Kufri Jyoti, thus confirming the findings of Shukla and Singh (1975) and Govindakrishnan *et al*, (1991).

Increase in the levels of nitrogen increased the yield of 'C' grade tubers but this increase was non significant .The highest yield of 'C' grade tubers was observed at 200 kg N ha⁻¹ and lowest at 120 kg N ha⁻¹. The results thus concluded corroborate with the findings of

Barevadia *et al*, (1978) and Singh & Sood (1996). Higher levels of nitrogen are reported to inhibit the activity of neutral peptides, hydrolyses probably causing delayed transport of metabolites from leaves into tubers and a rapid decrease in tuber size and yield.

Similarly the yield of 'C' grade tubers was not significantly affected by increase in levels of phosphorus. However, an increase in yield was observed when the level of phosphorus was raised from 80 to 120 kg P₂O₅ ha⁻¹. The highest yield of 'C' grade tubers was observed at 120 kg P₂O₅ and lowest yield at the lowest dose of 80 kg P₂O₅ ha⁻¹. Similar findings have been reported by Krishnappa (1989) and Deka and Dutta (1996).

5.4 Dry matter percentage.

Dry matter accumulation in plants is a photosynthetic and nutrient assimilation and utilization efficiency measurement.

In the present study dry matter (%) was estimated in the tubers.

Potato cultivars revealed an inherent property of difference in dry matter content of tubers. The highest dry matter content (20.13%) was observed in cv. PP-48 followed by cv. PP-2500 (19.86%) and Kufri Jyoti (19.0%). The differences were significant among all the cultivars. Similar findings have been reported by Das Gupta and Ghosh (1973) Shukla and Singh(1975), Sahota and Perumal(1986), Reddy *et al*, (1986), Trehan and Grewal (1991), Sud *et al*, (1991),Kushwah *et al*, (1993).

Increase in nitrogen levels increased the dry matter content upto 160 kg N ha⁻¹. The dry matter content increased from 18.81% at 120 kg N ha⁻¹ to 20.14% at 160 kg N ha⁻¹. But when the level of N was further increased to 200 kg ha⁻¹ the dry matter content decreased to 20.04% but this decrease was non-significant. It may be due to the fact that the higher levels of nitrogen enhanced the moisture uptake, which increased the water content in tubers. Similar results have been reported by Sud *et al*, (1982), Sahota and Premul (1986) and Hassandokht and Kashi (2000).

Increase in phosphorus levels increased the dry matter content upto 100 kg P₂O₅ ha⁻¹. The dry matter content of 19.32% was recorded at 80 kg P₂O₅ ha⁻¹ which significantly increased to 20.91% at 100 kg P₂O₅ ha⁻¹. But it was significantly reduced to 19.68% at 120 kg P₂O₅ ha⁻¹. Similar findings have been reported by Sharma *et al*, (1981) and Lal and Arora (1993).

5.5 Economics (Benefit- Cost Ratio)

Perusal of the Table-12 revealed that the application of 160 kg N ha⁻¹ with 100 kg P₂O₅ ha⁻¹ gave the maximum gross returns, net returns and benefit: cost ratio as compared to other fertility levels in all the three cultivars. The highest gross returns, net returns and benefit: cost ratio to the tune of Rs 1,77,080, Rs 1,03,070 and Rs 1.39, respectively was observed in cultivar PP-48 at the treatment combination of N₂P₂V₂. Prakash and Singh (1976)

reported that use of fertilizer, apart from irrigation is recognized as one of the quickest ways of increasing production of field crops. The extra returns obtainable depends on many other factors like climate, rainfall, soil type. Integrated insect pest management, cultural management measures and other factors. Under unfavorable conditions and poor crop husbandry, use of fertilizer may give only a marginal returns. Therefore, for a farmer it is essential to know the optimum manipulation of different production factors to harvest higher economic returns.

Table 12: - Benefit cost ratio

<i>Treatment combination</i>	<i>Average yield (q ha⁻¹)</i>	<i>Cost of cultivation (Rs. ha⁻¹)</i>	<i>Gross returns (Rs. ha⁻¹)</i>	<i>Net returns (Rs. ha⁻¹)</i>	<i>Benefit cost ratio</i>
<i>N₁P₁V₁</i>	256.76	73117	128380	55263	0.75
<i>N₁P₂V₁</i>	265.38	73576	132690	59114	0.80
<i>N₁P₃V₁</i>	260.83	74032	130415	56383	0.76
<i>N₂P₁V₁</i>	292.50	73555	146250	72695	0.98
<i>N₂P₂V₁</i>	330.50	74010	165250	91240	1.23
<i>N₂P₃V₁</i>	316.91	74466	158455	83989	1.12
<i>N₃P₁V₁</i>	285.33	73990	142665	68675	0.92
<i>N₃P₂V₁</i>	275.24	74446	137620	63174	0.84
<i>N₃P₃V₁</i>	252.13	74902	126065	51163	0.68
<i>N₁P₁V₂</i>	270.83	73117	135415	62298	0.85
<i>N₁P₂V₂</i>	293.66	73576	146830	73254	0.99
<i>N₁P₃V₂</i>	281.58	74032	140790	66758	0.90
<i>N₂P₁V₂</i>	323.00	73555	161500	87945	1.19
<i>N₂P₂V₂</i>	354.16	74010	177080	103070	1.39
<i>N₂P₃V₂</i>	344.75	74466	172375	97909	1.31
<i>N₃P₁V₂</i>	309.50	73990	154750	80760	1.09
<i>N₃P₂V₂</i>	287.90	74446	143950	69504	0.93
<i>N₃P₃V₂</i>	264.24	74902	132120	57218	0.76
<i>N₁P₁V₃</i>	249.16	73117	124580	51463	0.70
<i>N₁P₂V₃</i>	260.58	73576	130290	56714	0.77
<i>N₁P₃V₃</i>	245.00	74032	122500	48468	0.65
<i>N₂P₁V₃</i>	280.51	73555	140255	66700	0.90

$N_2P_2V_3$	301.24	74010	150620	76610	1.03
$N_2P_3V_3$	284.83	74466	142415	67949	0.91
$N_3P_1V_3$	259.74	73990	129870	55880	0.75
$N_3P_2V_3$	248.41	74446	124205	49759	0.66
$N_3P_3V_3$	224.16	74902	112080	37178	0.49

N_1 , N_2 and N_3 : Application of nitrogen @ 120, 160 and 200 kg ha⁻¹, respectively.

P_1 , P_2 and P_3 : Application of phosphorus @ 80, 100 and 200 kg ha⁻¹, respectively.

V_1 , V_2 and V_3 : Cultivars PP-2500, PP-48 and Kufri Jyoti, respectively.

Sale price of potato: Rs. 500 q⁻¹.

CHAPTER-VI

SUMMARY AND CONCLUSION

The present investigation was carried out at vegetable experimental field, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar campus during Kharif 2002 to study the “Response of potato cultivars to varying levels of nitrogen and phosphorus fertilization”.

The experiment was laid out in split-plot design with three replications. The potato cultivars viz. PP- 2500, PP-48 and Kufri Jyoti were planted in main plot with a spacing of 60 x 20 cm, while as combination of three levels of each nitrogen (120, 160 and 200 kg ha⁻¹) and phosphorus (80, 100 and 120 kg ha⁻¹) were tried in sub plots. Potassium was applied as per package of practices @ 100 kg K₂O ha⁻¹. The size of experimental plot was 3.0 x 2.0 m². Entire quantity of P and K was applied as basal dose. Half of nitrogen was applied at planting time and 2nd half at the time of first earthing up. Observations were recorded on different growth Parameters, yield, yield component traits and dry matter content.

The results revealed that among the cultivars, PP-48 recorded the maximum performance with respect to growth, yield, yield parameters and dry matter content. As compared to cv. PP-2500 and Kufri Jyoti, cv. PP-48 recorded the highest tuber yield of 303.28 q ha⁻¹, which was significantly higher than PP-2500 (281.73 q ha⁻¹) and Kufri Jyoti (261.51 q ha⁻¹).

Application of nitrogen upto 160 kg ha⁻¹ was observed to increase significantly the perse performance of the economic traits under study. The optimum tuber yield of 314.26 q ha⁻¹ was obtained with the application of 160 kg N ha⁻¹.

Application of phosphorus upto 100 kg P₂O₅ ha⁻¹ was observed to increase significantly the perse performance of economic traits studied. The optimum tuber yield of 290.78 q ha⁻¹ was obtained with the application of 100 kg P₂O₅ ha⁻¹.

From the present investigation it is concluded that the application of 160 kg N and 100 kg P₂O₅ ha⁻¹ with constant dose of 100 kg K₂O was found optimum for obtaining higher economic returns from the potato cultivars under Kashmir valley conditions.

Appendix- I: Weekly Meteorological data at Shalimar during cropping period for the year 2002.

<i>Standard week</i>	<i>Date</i>	<i>Temperature</i>		<i>Relative Humidity (%)</i>	<i>Rainfall (mm)</i>
		<i>Maximum</i>	<i>Minimum</i>		

12	19-25 March	16.5	6.3	66.14	10.28
13	26-01 April	18.30	4.7	61.16	0.4
14	2-8 April	15.5	6.5	63.28	4.7
15	9- 15 April	23.1	6.0	56.28	0.0
16	16-22 April	24.9	7.4	58.92	0.0
17	23-29 April	16.0	7.7	78.21	5.7
18	30-6 May	22.6	7.9	66.42	0.4
19	7-13 May	26.5	9.1	66.21	0.4
20	14-20 May	26.4	10	69.07	17.2
21	21-27 May	29.1	8.9	52.5	0.0
22	28-3 June	29.6	11.6	59.2	19.4
23	4-10 June	29.6	12.4	58.28	5.0
24	11-17 June	29.5	14.2	66.21	11.9
25	18- 24 June	28.4	14.3	67.8	3.9
26	25-1 July	28.8	16.0	73.28	18.0
27	2-8 July	31.4	15.3	69.92	0.0
28	9-15 July	31.1	14.8	68.14	0.0
29	16-22 July	31.0	17.1	61.28	3.5
30	23-29 July	29.5	14.8	70.71	13.2

Source: Meteorological observatory, Division of Agronomy, SKUAST(K) Shalimar, Kashmir.

Appendix-II: - Analysis of variance for the effect of different levels of nitrogen and phosphorus on growth parameters in potato cultivars.

<i>Source of variance</i>	<i>D. F.</i>	<i>Mean squares</i>		
		<i>Emergence percentage</i>	<i>Plant height (cm)</i>	<i>Number of shoots plant⁻¹</i>
Replication	2	132.200	0.392	0.588
Cultivar (V)	2	171.826*	279.103**	18.520**
Error (A)	4	22.589	0.297	0.700
Nitrogen (N)	2	3.244	112.546*	2.981**
V x N	4	7.307	1.725**	0.548
Error (B)	12	22.173	0.204	0.375
Phosphorus (P)	2	0.024	2.823**	0.011
V x P	4	3.758	1.251	0.148
N x P	4	1.115	0.366	0.192
V x N x P	8	2.124	0.380	0.223

Error (C)	36	19.264	0.530	0.298
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*, **. Significant at 5 and 1 percent level, respectively.

Appendix-III: - Analysis of variance for the effect of different levels of nitrogen and phosphorus on yield and yield attributes in potato cultivars.

<i>Source of variance</i>	<i>D. F.</i>	<i>Mean squares</i>			
		<i>Tuber number plant⁻¹</i>	<i>Average tuber weight (g)</i>	<i>Tuber weight (kg) plant⁻¹</i>	<i>Tuber yield q ha⁻¹</i>
Replication	2	0.542	0.217	0.00006	210.839
Cultivar (V)	2	52.447**	59.398**	0.0159**	30120.294**
Error (A)	4	0.153	0.277	0.0001	56.667
Nitrogen (N)	2	11.742**	53.060**	0.0282**	18652.371**
V x N	4	0.584**	10.669**	0.0013**	742.986*
Error (B)	12	0.300	0.347	0.00002	168.368
Phosphorus (P)	2	0.487*	1.862*	0.0029**	955.341**
V x P	4	0.082	0.260	0.0001	203.083
N x P	4	1.588**	7.477**	0.0021**	776.040**

V x N x P	8	0.230	0.164	0.0002	260.722
Error (C)	36	0.160	0.707	0.00008	153.676

***, **. Significant at 5 and 1 percent level, respectively.**

Appendix-IV: - Analysis of variance for the effect of different levels of nitrogen and phosphorus on tuber yield in grades and dry matter content in potato cultivars.

<i>Source of variance</i>	<i>D. F.</i>	<i>Mean squares</i>			
		<i>Grade 'A'</i>	<i>Grade 'B'</i>	<i>Grade 'C'</i>	<i>Dry matter percentage</i>
Replication	2	0.0001	0.00002	0.0103	0.0184
Cultivar (V)	2	0.0043**	0.00133**	0.0100	4.584**
Error (A)	4	0.0001	0.00001	0.0085	0.1226
Nitrogen (N)	2	0.0019*	0.00002	0.0071	7.3099**
V x N	4	0.0006*	0.00016**	0.0126	12.7878
Error (B)	12	0.0002	0.00002	0.0080	0.0357
Phosphorus (P)	2	0.0080**	0.0014**	0.0039	1.4586**
V x P	4	0.0002	0.000014	0.0080	0.4812
N x P	4	0.0080	0.000012	0.0080	0.8909

V x N x P	8	0.0002	0.00007	0.0075	0.4209
Error (C)	36	0.0001	0.000028	0.0079	0.0567

*, **. Significant at 5 and 1 percent level, respectively.

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*Original not seen.

CERTIFICATE

This is to certify that all the corrections and modifications suggested by the external examiner in the thesis script of Mr. Mohammad Maqbool Bhat (Registration No. 2001- A- 645- M), entitled “Response of Potato cultivars to varying levels of nitrogen and phosphorus fertilization” have been taken care of before final binding of the same.

Chairman *(Dr. G. M. Lanker)*

Advisory committee