STUDIES ON THE EFFECT OF PERIOD OF SPROUTING AND DATE OF PLANTING ON PRODUCTIVITY, QUALITY AND STORAGE BEHAVIOUR OF POTATO (*Solanum tuberosum* L.)

THESIS

BY

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Submitted to

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IN

Partial fulfilment of the requirements for the degree

OF

MASTER OF SCIENCE IN AGRICULTURE
(AGRONOMY)

1994

Dedicated
To My
Respected Parents

<u>CERTIFICATE-I</u>

This is to certify that the thesis entitled "Studies on the effect of period of sprouting and date of planting on productivity, quality and storage behaviour of potato (Solanum tuberosum L.)" submitted for the degree of MASTER OF SCIENCE (Agriculture) in the subject of Agronomy of Himachal Pradesh Krishi Vishvavidyalaya, Palampur, is the bonafide research work carried out by Mr. Chaman Lal, son of Shri Jagga Ram, under my supervision and that no part of this thesis has been submitted for any other degree.

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

Palampur

Dated: 3.8.94

(J. Shekhar)
Major Advisor

CERTIFICATE-II

This is to certify that the thesis entitled "Studies on the effect of period of sprouting and date of planting on productivity, quality and storage behaviour of potato (*Solanum tuberosum* L.)" submitted by Chaman Lal, son of Shri Jagga Ram to the Himachal Pradesh Krishi Vishvavidyalaya, Palampur, in the partial fulfilment of the requirements of the degree of MASTER OF SCIENCE (Agriculture) in the subject of Agronomy has been approved by the Student's Advisory Committee after an oral examination of the student in collaboration with the External Examiner.

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(Chaman Lal)

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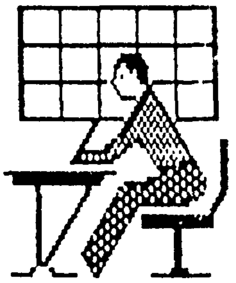


INTRODUCTION

1. INTRODUCTION

Potato (Solanum tuberosum L.) is an important vegetable source of low cost energy with a high content of starch (70%) and medium to high contents of vitamins especially, C and B_1 and minerals. The crop commands high preference with the farming community of India as well as Himachal Pradesh. The primary factor responsible for the higher acceptability of this crop in Himachal Pradesh is its shorter growth duration, versatility of adaptation under various agroecological conditions and high responsiveness to the agronomic manipulations in comparison to the other competing cash crops like ginger and sugarcane, etc. or perhaps higher economic returns/rupee investment over cash generating agricultural activities like vegetable seed production. The average potato productivity which is 16.2 t ha^{-1} on national basis is only 8.2 t ha^{-1} in Kangra district of Himachal Pradesh with an area of 941 hectares, (Anonymous, 1991). There is thus, need of intensive efforts to realize the high yield levels of 28.8 t ha^{-1} recorded by Kataria (1987) and 24.8 t ha^{-1} by Manchanda (1989) for this region. The important reason for low productivity appears to be the poor agronomic management of the crop in respect of planting time, selection of seed and cultivar, application of irrigation water and nutrients (comprising quantity as well as quality) and pest management technology. Climate with particular reference to air and soil temperatures at the time of planting also requires its due mention. In Kangra district, potato is an important spring season crop with planting time extending over whole January to early February. The mean temperature during the planting time ranges between 5 to 15^{o}C and remains well below optimum (18-20^{o}C) upto end of March. Experimentation under mid hill conditions of Himachal Pradesh has revealed that potato crop takes around 78-82 days for its complete emergence (Kataria, 1987) resulting in shortened growth cycle from emergence to maturity and finally reduced crop yields.

Use of mulches (vegetative, plastics, etc.) and the practice of sprouting potato seed tubers before planting (which is oftenly not practised) are the components of accepted technology used to overcome the adverse effects of low temperature on potato. The former, though effective, is beyond the scope as well as means of poor hilly farmers. Alternatively, the latter, i.e. the practice of sprouting seed potato before planting (commonly referred to as pre-sprouting) may be used to mitigate the adverse effects of low temperature and ultimately ensuring enhanced potato productivity. Use of presprouted seed helps in emergence of shoots immediately after planting even when soil temperature is low (Whitehead, et al., 1953).

Also, the planting of sprouted seed potato may be delayed until soil conditions are favourable without appreciable adverse effects on crop yield (Whitehead et al., 1953). This delay in planting of spring potato implies availability of some extra time for the autumn sown crops and is of particular importance for the success of multiple cropping systems.

Timely sowing of crop is the most important non-monetary input for higher crop productivity. A given planting time is linked to a particular set of climatic conditions particularly thermal environment which exerts its effect on productivity of potato through its influence on crop growth and development. Further, sowing time may vary with varieties suggesting that the performance of a given potato cultivar depends on its time of planting (Khurana and Pandita, 1986). Cultivars are also known to respond differently to varying durations of sprouting (Allen et al., 1927).

After harvesting, the potato is stored to provide a uniform flow of tubers to the market and processing units. During storage, potato is subjected to various kinds of losses due to respiration, evaporation of water from tubers and rottage in material due to various storage pests and diseases (Singh and Shrivastava, 1983). Sprouting of potatoes leads to both quantitative and qualitative loss of tubers due to higher water loss, softening and sweetening of tubers. The extent of these losses determines the real value of potato harvest. Experimentation has proved that storage losses are linked to cultivar as well as growing conditions (Wilcockson et al., 1985).

Information on the aspects discussed above is lacking for the mid hill conditions of Himachal Pradesh. The present study has therefore, been carried out with the following specific objectives:

i To study the effect of sprouting on growth, yield attributes and productivity of potato, ii to standardise the optimum time of planting,

iii to compare the performance of promising potato cultivar QB/A-9-120 against standard Kufri Jyoti,

iv to study the effect of different experimental factors on storage behaviour of potato, and

v to study the interaction effect, if any, between various experimental factors on potato crop.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The literature available on the effect of duration of sprouting of seed potato, date of planting and cultivars on growth, tuber yield, quality and storage behaviour of the produce has been reviewed and presented in the following sections of this chapter.

2.1 EFFECT OF DURATIONS OF SPROUTING

2.1.1 Growth and development

Sprouting the seed potatoes in order to hasten plant growth, tuberization and bulking of potatoes has been prevalent in many countries, since decades. Field experiments under Indian conditions by Sinha (1974) and Jain and Sinha (1982) showed that sprouting seed potatoes invariably accelerated plant emergence and its growth and tuberization were faster in sprouted tubers than unsprouted ones and this was more prominent upto about 11 weeks growth stage.

Sinha and Rai (1982) reported that potato seed sprouted for four weeks showed faster plant emergence at each date of planting compared with that sprouted for seven weeks which lost vigour due to shrinkage as a result of longer period of sprouting under high temperature conditions. Later studies by Sinha and Rai (1985) have shown that four weeks sprouted seed tubers emerged first closely followed by two weeks sprouted tubers at each date of count. Unsprouted seeds however, emerged at a slow pace. By four weeks, 90-95% plant emerged in all treatments.

Reust et al. (1982) and Hamouz (1989) reported that chitting resulted in early emergence of potato as compared to unchitting. Klamke and Moll (1988) pointed out that for late planting differences in time taken for emergence between sprouted and unsprouted seed potatoes were very small but for early planting pre-sprouted seed tubers emerged earlier than did unsprouted tubers.

Eastman and Libby (1947) reported that a combination of sprouting and thio-urea treatment would be practical for seed potatoes which required to be harvested early.

Puscharew (1933) found an early plant emergence and flowering as a result of sprouting seed tubers. It was also reported that sprouting of the day (six hours) during sprouting of the seed, caused in all cases, earlier tuberization as well as plant ripening (maturity) than chitting in 12 hours of light.

Khan et al. (1980) reported that plant height, number of branches and dry weight/plant increased significantly with increase in chitting period from 5 to 15 days under Faisalabad (Pakistan) conditions. According to Moorby (1967), presprouted seed tubers bore a single sprout with well developed branches which produced many tubers as did many poorly developed sprouts.

Johnnes(1988) reported that average daily weight gain of tubers of early potatoes was 1.0-1.2 t ha^{-1} greater when seed tubers subjected to prolonged intensive presprouting had been planted than when seed tubers sprouted in January, February, March were grown and harvested so as to modify dormancy. Crops from intensively sprouted seed could be harvested 2-3 weeks earlier than those grown from the other treatments without loss of economic returns.

2.1.2 Tuber yield and quality

Total tuber yield from large grade (50-60 mm) sprouted seed tubers was higher (30.7 t ha^{-1}) as compared to unsprouted seed (23.8 t ha^{-1}) (Saunders and Hutchinson, 1984). However, when medium sized seed tubers were used, the yield differences between sprouted and unsprouted seeds were not as wide (28.5 t and 26.0 t ha^{-1}, respectively). They also reported that dormancy breaking of daughter seed tubers (30-60 mm) was faster in plants obtained from sprouted seed tubers. Marinis (1979) reported higher tuber yields from seed tubers planted after sprouting as compared to when seed tubers were planted without sprouting during all the three years of the study.

Kondratowicz and Paprocki (1985) reported that initial sprouting of seed potato increased tuber yield and starch content particularly at the two latest plantings (May 18 and June 1). Szysz and Songin (1987) found that chitting before planting increased the content and yield of starch.

Krijthe (1962) who reported higher yield of potatoes due to sprouting, observed that there was apparently not much loss of weight of sprouted seed tubers during sprouting period resulting in higher proportion of ware and less quantities of seed and chat tubers.

Banerjee et al. (1978) found that sprouting seed tubers for three weeks gave higher yields than sprouting for one week or no sprouting. Similarly, Jain and Sinha (1982) observed that sprouting seed potato for four weeks resulted in more tuber yield compared with sprouting for two weeks or unsprouting treatment upto 11 weeks growth stage after which the trend reversed and it was observed that the produce of tubers in each grade was fairly high in plants from unsprouted seed tubers. Conversely, if the plants are damaged due to frost or late blight or virus at later stages, the tuber yield from plants of sprouted tubers would be naturally high. Yet another study by Sinha and Rai (1985) revealed that sprouting for seven weeks showed marked reduction in the yield of potatoes compared to sprouting for four or one week duration, the latter two treatments, however, comparing well with each other at all stages of growth and development of potato tubers.

Thomas and Eyre (1951) summarising results of 1465 experiments from Ireland reported approximately 20 per cent higher tuber yield from the use of sprouted seed over unsprouted seed. Similarly, Dyke (1956) noted that the sprouted seed at Craibstone out yielded the unsprouted seed by an average of 1.7 t $acre^{-1}$ for planting in March and 2.5 t $acre^{-1}$ for planting in mid-April.

Furunes (1990) reported that the total yield increased from presprouting from 4.5 t ha^{-1} to nearly 11.0 t ha^{-1} and presprouting also increased the tuber dry matter content. Similarly, Davidson (1934) reported that sprouting the seed increased the yield by from 30 cwt to 2 t $acre^{-1}$ in an average season.

Hanlan (1929) reported that the resultant crop from sprouted seeds of the variety Irish Cobbler was ready for use twelve days earlier than that from unsprouted tubers and also that an average increase in yield of 44 bushels $acre^{-1}$ of marketable potatoes was obtained at full maturity of the crop. With the variety Green Mountain, nine days in earliness and 31 bushels $acre^{-1}$ in yield were gained from the sprouted tubers.

Hardenburg (1928) explained that the crop from sprouted seed developed a higher tuber set than that from unsprouted seed because of shortening of the internodes and the corresponding increase in node number on the underground portion of the stem.

Initial sprouting of seed potatoes increased tuber yields from 28.9 to 31.2 t ha^{-1}, average starch yield from 4.38 to 4.78 t ha^{-1} and average protein yield from 602 to 647 kg ha^{-1} (Kondratwicz and Paprocki, 1985).

Reust (1990) reported that cultivars differ in their chitting requirement and that chitting for the recommended period increased the tuber yield of all the cultivars under study.

2.2 EFFECT OF DATESOF PLANTING

2.2.1 Growth and development

Time of sowing/planting influences growth, development and crop productivity and potato for that matter is no exception to it. Demagante and Vander (1988) from an experiment involving five dates of planting spread over October to January observed that plants grew faster and tuberized earlier with later planting dates. Roztropowics and Wardzynska (1975) reported growth acceleration as a result of late planting. However, no differences were observed in tuber emergence between three planting dates (February 20, March 1 and March 10) and between three varieties viz., Cardinal, Desiree and Radosa. Matlob and Mahmood (1984) reported that total plant dry weight increased by early planting.

Khalel et al. (1986) observed that when potato cv. Clauster was planted on 15 and 25 February and 7 March, the plant height, the number of stems/plant and dry weight of above and below ground plant parts as well as whole plant dry weight increased with delay in planting. Samul (1984) also observed increased culms/plant with delay in planting. Haulm yield was, however, reported to be higher with early planting and reached a maximum at flowering.

Late spring planting (15 March or 1 April) increased early vegetative growth whereas, early planting (1 or 15 February) stimulated vegetative growth at later stage (Moharam and Abdul, 1987). Ezekiel and Bhargava (1992) reported that delayed planting decreased plant height, leaf number, LAI and total dry matter production due to sub-optimal night temperature. Similarly Perumal (1981) from his experiments with potato cv. Kufri Jyoti planted on four different dates during spring under Shillong conditions showed that in early planted crop, the LAI was initially low, which gradually increased and the maximum LAI occured with the onset of tuber bulking. In delayed plantings, LAI was initially high and maximum LAI was attained comparatively earlier leading to growth acceleration and early senescence. Besides, the crop duration was also shortened by the incidence of blight disease. He also observed a decrease in number of tubers/plant with delay in planting.

Tuber formation in cv. Desiree started after 51, 46 and 48 days for planting done on 18/11, 18/12 and 18/1, respectively, thereby indicating early onset of tuber formation for late planted potatoes (Torres, 1982).

Rashid and Ali (1992) from his experiment with two commercial potato varieties under Bangladesh conditions indicated that November 10 to 20 is the best time of planting for the production of seed potatoes whereas, for table potatoes planting can be delayed upto Ist December. Later plantings were associated with weaker plant stand due to physiologically old seeds which resulted in early tuberization, smaller tuber production, more virus infection and low yield.

Ezekiel and Bhargava (1992) observed that the planting date had a significant effect on plant emergence, crop growth, crop duration and tuber yield. Higher tuber yield in optimum planting was due to higher total dry matter production as a result of greater LAI and CGR. In delayed planting LAI and CGR were adversely affected by low temperature.

Khurana and Pandita (1986) revealed that planting on 18 and 22 October markedly decreased the leaf weight in cv. Kufri Chandramukhi throughout the growth period compared with planting on earlier dates (2,7,12 October), late planting also decreased leaf weight in Kufri Sindhuri during early growth period but did not differ significantly during late growth stages.

2.2.2 Tuber yield and quality

Caliskan and Incekara (1987), who studied the effect of twelve planting dates on three early and two late potato cultivars concluded that planting in January, February and March gave higher yields whereas, yields after planting in July and August were moderate and in May and June low. Height and tuber yield were negatively correlated. The researchers further reported that starch contents were high in January to March and August planting but decreased by September.

Manchanda (1989), with the objective of finding out best time of planting potato crop under Palampur conditions, raised potato at fortnightly interval throughout the year. For the main crop (spring crop), the researcher reported first week of February as the best planting period from the tuber yield point of view.

Under the agroclimatic conditions of Kanke (Bihar), Sharma and Verma (1987) reported that October 30 planting gave higher yield than earlier (October 15) or late plantings (Nov. 15 and Nov.30) and tuber yield increased with delay in harvesting. Krishnappa (1991) reported that mean tuber yields were higher than 30 t ha^{-1} when planted between 30 October and 30 November and decreased with later planting. Yield differences were associated with fewer tubers/hill.

Planting on 20 October in Madhya Pradesh gave the highest tuber yield of variety Kufri Sindhuri in both years (Gupta et al., 1991). Delay in planting after this date considerably reduced the yields. Number and weight of tubers/plant were also highest with 20 October planting dates.

Similarly, Ahmad and Samad (1976) and Matlob and Mahmood (1984) reported decrease in tuber yield with delay in planting dates. Ahmad and Samad (1976) also reported that highest tuber yields were obtained with November planting at all the four locations and yield declined with delay in planting to 38-78% of the yield with November planting.

Kaznacheev (1987) reported higher tuber yields of three potato cultivars planted on 8-14 May than when planted on 16-21 May or 24-28 May. Likewise Kondratowicz and Paprocki (1985) reported reduced average tuber yields of 26.5 t ha^{-1} for June 1 planting compared with 32.0 and 30.0 t ha^{-1} for planting on 20 April, 4 or 18 May. Late planting also reduced starch and protein yields.

Gupta (1990) observed that the planting of tubers on 22 April at 1800 m above MSL and 18 May at 2700 m above MSL gave higher yields of variety Kufri Jyoti than later planting. The percentage of small tubers (<25 mm) increased with delay in planting dates from September to beginning of January under Srilanka conditions (Kuruppuargchchi, 1987). On the other hand

Perumal (1981) reported an increase in number of tubers with a significant increase in tuber yield, when crop was planted early. Likewise Samul (1984) reported that delay in planting reduced the number of tubers/plant in all varieties. At Shilong (Meghalaya) cv. Kufri Jyoti planted on 5,15 or 25 March gave the highest tuber yields when planted on 5 March (Murti et al., 1977).

Average tuber specific gravity of five potato cultivars planted on 15 Aug., Sept., Oct., Nov. or December decreased as planting was delayed until October and then increased in December. Plooy and Prinsloo (1980) reported low specific gravity of potato in seasons with high temperature and poor rainfall distribution.

Ronsen and Ekeberg (1984) from field trails with potato planted in spring or 2 or 4 weeks later reported that planting at the first and second dates gave similar tuber yields but later planting gave lower yields. Dry matter content decreased by 0.1% for each day's delay in planting.

Kabir et al. (1991) concluded that the mean yields of three different planting times did not differ significantly but varied within varieties with Patrones appearing to be more responsive to early planting, Kufri Sindhuri to late planting and Cardinal to mid November planting. Early planting was found to bulk late and late planting was found to bulk early. The mid November was found to yield the highest but statistically similar to November 1 and November 30 plantings.

2.2.3 Storage behaviour

Wilson et al. (1962) suggested that for main (spring) crop stored in stacks, shrinkage may account for a 7% loss of the original weight of tubers put into store by the end of May which is equivalent to about 0.22% per week. If not supressed, sprouting might be expected to cause an additional 4% loss over the same period of storage.

Singh (1957) reported that rotting decreased and sprouting was delayed in the produce of the successively later plantings. As deferred planting delays the onset of tuberization, a corresponding shift in sprouting is understandable. The reduction in rotting in later plantings is possible due to shorter period over which tubers remain in contact with soil.

2.3 EFFECT OF CULTIVARS

2.3.1 Growth and development

Sahota and Perumal (1986) observed that cv. Kufri Khasigaro produced more vegetative growth than cv. Kufri Jyoti at all the stages of crop growth except in initial stages during the crop season. The tuberization was found to be earlier in Kufri Chandramukhi in spring and summer crop seasons. However, in spring season, cv. Kufri Khasigaro started late tuber initiation and slow tuber enlargement resulted in continuous growth of the foliage and LAI increased till harvest. The number of tubers per plant was less in Kufri Sindhuri, due to late tuber initiation under long days (Mehta et al., 1988).

Ezekiel (1990) recorded maximum plant height, leaf number and stolon length (10.6 cm) in PCN/76-110 and minimum in SLB/M-70. Misra and Mohanty (1973) showed that the variety Kufri Sindhuri recorded highest shoot length, maximum number of shoots/plant and total number of leaves/plant followed by Up-to-Date and Kufri Chandramukhi in that order. Pushkarnath (1969) also reported higher plant height and number of leaves/plant in case of Kufri Sindhuri.

2.3.2 Tuber yield and quality

Lal and Sahota (1983) observed that Kufri Jyoti performed better when planted on 5th and 15th March whereas, Kufri Khasigaro had an edge over Kufri Jyoti when planted on 25th March. Experiments conducted at Modipuram (Meerut) revealed that Kufri Bahar yielded 18% higher than Kufri Chandramukhi and this yield increase was mainly in the production of large sized tubers (50%) in Kufri Bahar (Singh, 1982). Verma et al., (1985) found that total yield of Kufri Chandramukhi was most stable followed by Kufri Sheetman, Kufri Lalima and Kufri Bahar and for yield of tubers above 50 mm in diameter in the produce, variety Kufri Bahar was most stable followed by other varieties.

Sulaeman (1988) reported that tuber yields of different cultivars ranged from 5.66 t ha^{-1} (cv. Gabriella) to 15.30 t ha^{-1} (cv. Cosima). The yield of tubers <20 g, 20-60 g and >60 g was highest for cv. Gratta, Cosima and Cosima, respectively. Total tuber yield of Gratta (12.48 t) compared well with that of Cipanas (11.60 t). Ezekiel (1990) while working under the agroclimatic conditions of Ootacamund

(Nilgiris) attributed higher yield in variety PCN/76-110 over SLB/M-70 to longer crop duration, higher harvest index, leaf area index and net assimilation rate.

Maity and Arora (1980) found that the variety Kufri Sheetman produced highest tuber yield, followed by Kufri Chandramukhi and Kufri Lauvkar. The Kufri Lauvkar produced tubers with higher mean weight and greater proportion of ware sized tubers. The high yielding ability of Kufri Sheetman may be attributed to its higher mean leaf area index and leaf area duration. The variety Kufri Sheetman produced tubers with significantly higher dry matter percentage as compared with Kufri Chandramukhi and Kufri Lauvkar. Kufri Sheetman produced more number of tubers than the other two varieties.

Maximum number of tubers per hill were recorded in the cultivars Kufri Lauvkar and JE-808. The difference in tuber number might be related with number of stems per hill (Toosey, 1962). Pushkarnath (1969) and Singh (1981) reported that variety producing numerous thin stems had large number of tubers. Sikka et al. (1974) and Randhawa et al. (1972) have found significant differences among various potato cultivars with respect to number of tubers and yield/plant.

Kabir et al. (1991) reported that yield increased significantly upto 80 days in all varieties and Kufri Sindhuri was the highest yielder followed by Cardinal and Patrones. Similarly, Misra and Mohanty (1973) also observed that the variety Kufri Sindhuri produced more tubers as well as total tuber yield than Up-to-Date and Kufri Chandramukhi.

2.3.3 Storage behaviour

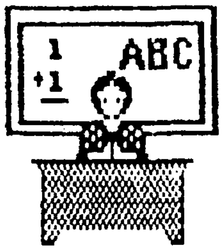
Varieties have been reported to respond differently to natural storage conditions. While some were more susceptible to losses during storage due to very high temperature and low humidity, others were having low susceptibility (Niphade and Mahajan, 1976).

Bhatnagar and Singh (1985) reported that weight loss in tubers stored at 35 ± 1^{o}F for 7 months was 6.9-18.8%. It was the lowest (6.9-7.1%) in Up-to-Date and Kufri Chandramukhi, while the low temperature inhibited sprouting in all cultivars. Krijthe (1962) studied the effect of temperature on potato storage and found that at 25^{o}C, 21 varieties out of 35 examined did not sprout sooner than at 21^{o}C. Of the remaining fourteen, the largest difference occured in the varieties Alpha, Ackersegan and Arran Banner, in which sprouting at 25^{o}C took 3, 3 and 6 weeks less, respectively, than at 21^{o}C. The differences increased as the temperature was reduced. There were no differences between cv. Spunta and Sebago at 10^{o}C (Dogras et al., 1971). Further, there was no sprouting at 6^{o}C after 8 weeks storage but at 10^{o}C sprouting occured in both cultivars and was greater in cv. Sebago.

Studies by Koul and Mehta (1987) on table potatoes of four cultivars stored without refrigeration at 21-40^{o}C for 120 days showed 100% sprouting, 14-20% weight loss, 1-24% rottage and 71-320 g sprouts kg^{-1} tubers at the end of the storage period.

In all the 27 genotypes studied, rottage, weight loss and sprouting ranged from 3.9-30.5%, 7.5-23.9% and 6.0-75.2 g sprouts kg^{-1} of tubers, respectively (Singh, 1988). Keeping quality of Kufri Dewa was best in ordinary store followed by JH-222, Kufri Lalima and Kufri Chandramukhi in that order. Observations on cultivars stored under natural conditions in Kassel (Germany) revealed that storability varied significantly between cultivars (Kolsch et al., 1991). Similarly, observations by Wustman et al. (1987) with 10 promising cultivars grown on peat soils in the Netherlands revealed significant differences among cultivars with respect to susceptibility to damage, weight loss and starch loss during storage at 6^{o} or $20^{o}C$ and development of rotting at $20^{o}C$. Astrate had high weight loss and Elkana and Prominent low losses.

Martin et al. (1925), Emilson (1949) and Wilson et al. (1962) reported that varieties differed markedly in their rate of sprout growth. For example, Arran Pilot sprouted very soon after harvest, sometimes even before and exhibited a very rapid rate of growth. Majestic, on the other hand, had a slow rate of sprout growth and sprouting did not normally start till several weeks after harvest.



MATERIALS AND METHODS

3. MATERIALS AND METHODS

The experiment entitled "Studies on the effect of period of sprouting and date of planting on productivity, quality and storage behaviour of potato (*Solanum tuberosum* L.)" was conducted at the Experimental Farm of the Department of Vegetable Science and Floriculture, Himachal Pradesh Krishi Vishvavidyalaya, Palampur (H.P.) during spring season of 1993. The details of materials used and methods adopted during the course of these investigations are presented in this chapter.

3.1 EXPERIMENTAL SITE

3.1.1 Location

The experimental farm is situated at $32^{o}6'$ N latitude and $76^{o}3'$ E longitude at an elevation of about 1290.8 m above mean sea level. It falls in the mid-hill zone of the Shiwalik ranges of Himachal Pradesh.

3.1.2 Climate

The region represents mid-hill sub humid agroclimatic zone of Himachal Pradesh and is characterized by wet temperate climate with severe winters and mild summers. The mean annual rainfall of the experimental site is 2731.8 mm (average of 10 years) about three fourth of which is received from July to September. The monsoon generally sets in by the fourth week of June and remains active during July and August.

The meteorological observations on maximum and minimum temperatures, relative humidity, rainfall, sunshine duration and evaporation during the crop season as recorded at the Agrometeorological observatory of the Department of Agronomy, HPKV, Palampur have been illustrated graphically in Fig. 1 and given in Appendix I.

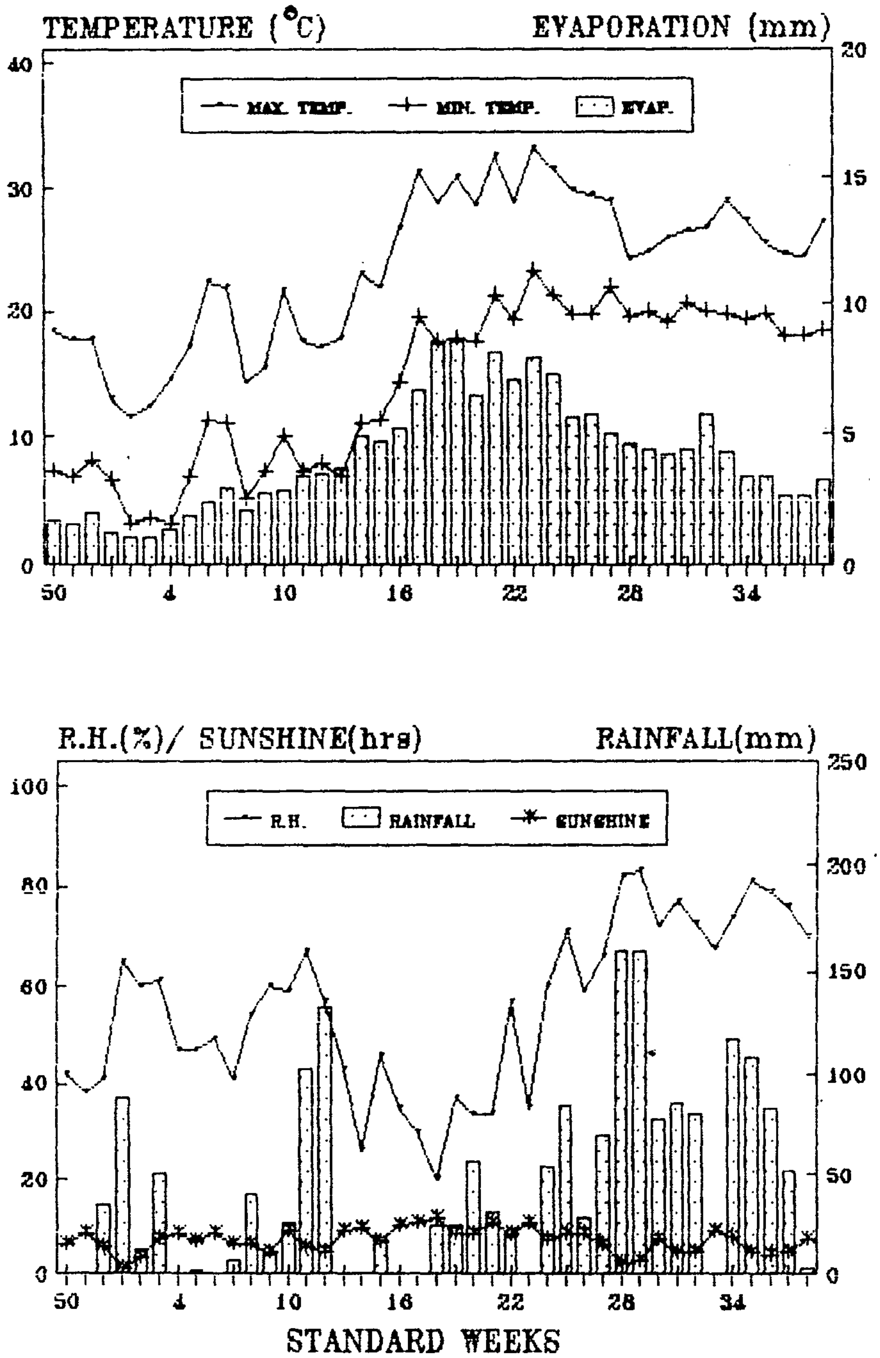


Fig.1 Mean weekly meteorological data during experimental period (*Dec.92 to Sept.93*)

3.1.3 Soil

Three composite soil samples were taken from 0-15 cm depth in each replication and analysed for their physical and chemical properties. The results obtained have been presented in Table 1. The soils acidic in reaction (pH 5.5), silty clay loam in texture, high in available N and medium in available P and K are taxonomically classified as Typic Hapludalfs.

Table 1. Physico-chemical properties of soil

Sr. No.	Soil properties		Method employed
1.	Soil pH	5.5	1:2.5 soil water suspension using glass electrode pH meter (Jackson, 1967).
2.	Organic carbon (%)	1.23	Walkley and Black's rapid titration method (Walkley and Black, 1934).
3.	Particle size distribution (%)		
	i) Sand	16.7	International pipette
	ii) Silt	52.2	method (Piper, 1966).
	iii) Clay	30.5	
4.	Textural class	Silty clay loam	
5.	Cation exchange capacity (C mol $P^{+}kg^{-1}$)	7.8	Ammonium Acetate (Chapman, 1965).
6.	Available Nutrients (Kg ha^{-1})		
	i) N	751.1	Alkaline permanganate method (Subbiah and Asija, 1956).
	ii) P	20.6	Olsen's method of extraction with 0.5 N $NaHCo_3$ at pH 8.5 (Olsen et al., 1954).
	iii) K	267.2	Extraction with N neutral Ammonium acetate and flame photometric determination (Merwin and Peech, 1950).

3.2 EXPERIMENTAL DETAILS

The field experiment consisting of sixteen treatment combinations replicated thrice in split plot design was conducted during spring 1993. The experimental details are given in Table 2.

Table 2. Detail of treatments

Factor	Detail	Symbol
A. Main Plot Factors:		
Date of planting	a) 25 January	P_1
	b) 9 February	P_2
Cultivar	a) QB/A-9-120	V_1
	b) Kufri Jyoti	V_2
B. Sub Plot Factor:		
i) Duration of sprouting (Days)	a) 0 (control)	S_1
	b) 15	S_2
	c) 30	S_3
	d) 45	S_4

The field layout plan is illustrated in Fig. 2.

3.3 FIELD OPERATIONS

3.3.1 Field preparation

The experimental field was ploughed once with tractor drawn disc plough followed by two harrowings and one planking. Before ploughing, the field was irrigated to ensure adequate moisture for planting. Field layout was completed as per details given in section 3.2.

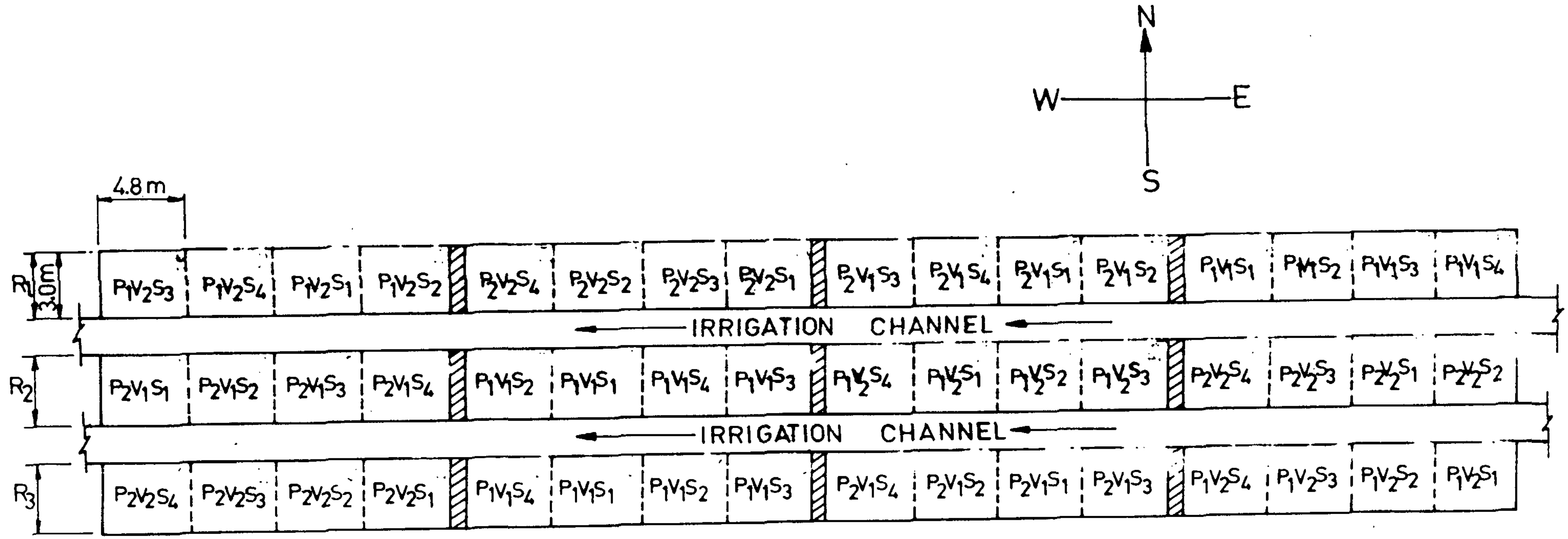


FIG. 2 : PLAN OF LAYOUT

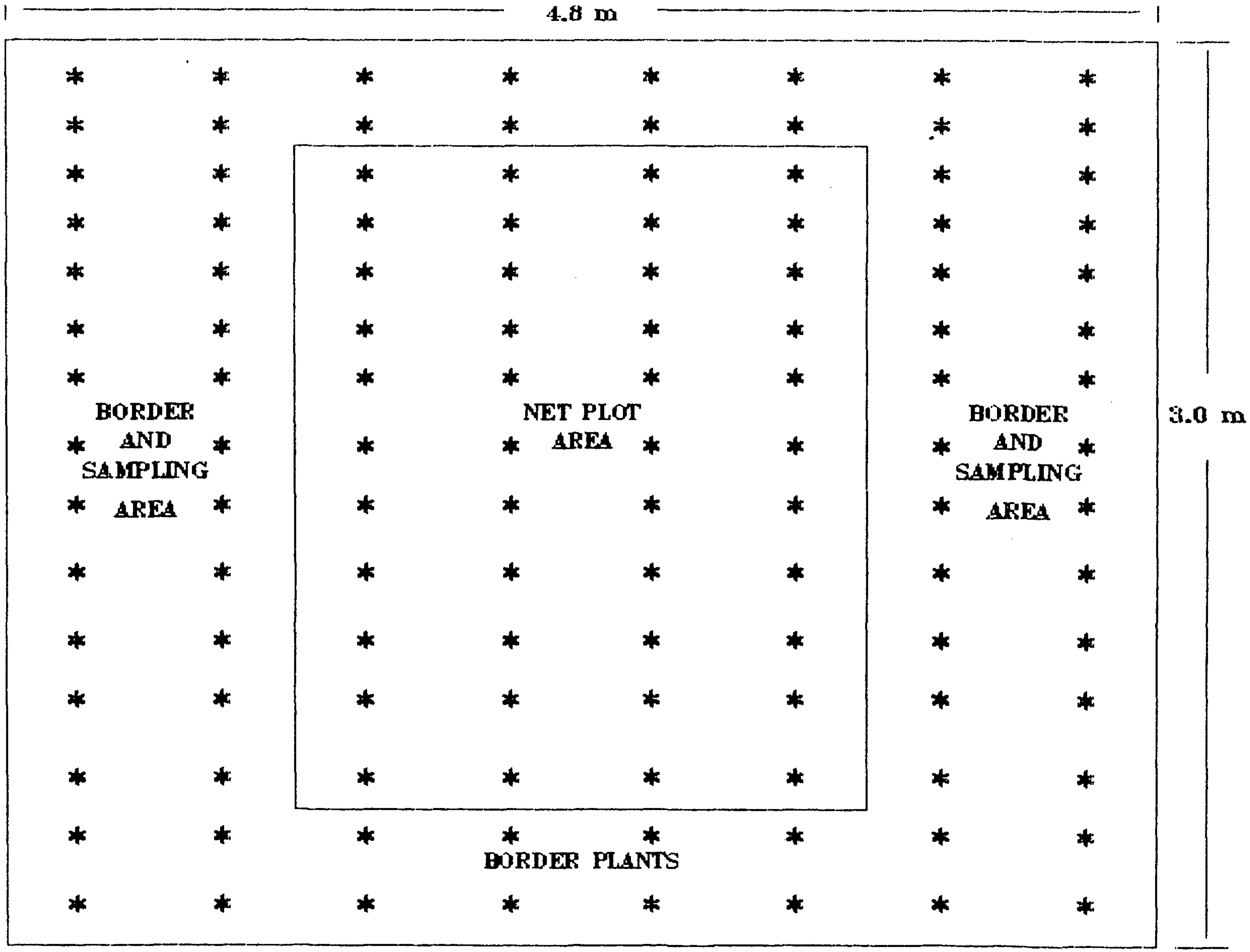


Fig.3 Details of individual plot & sampling area

3.3.2 Seed preparation

Seed tubers were made to sprout by exposing them to sunlight for a specified period (as per treatments). For this purpose required quantity of seed tubers of each variety was taken and kept in bamboo baskets separately for easy handling. From 5.00 PM to 9.00 AM the seed tubers were kept in seed store (ordinary room in a *katcha* building). Whenever it rained during the day or there happened to be a overcast sky, the seed tubers were shifted to the seed store. In order to protect the seed tubers from direct sunlight, baskets were kept covered with gunny bags during day time.

The observations on sprouted tubers (%), sprout length (having length $\geq$ 3 mm) and number of sprouts on seed tubers were recorded one day before planting and are presented in Table 3.

A day before the scheduled date of planting the seed tubers were cut into seed size pieces (25-30 g) treated with 0.25% solution of Dithane M 45 for 10 minutes against tuber borne fungal diseases. The cut seed tubers were then kept in a heap for 16-20 hours and were planted as per schedule.

3.3.3 Planting and basal application of nutrients

After final plot levelling (as per date of planting treatments) shallow furrows (5-7 cm deep) were opened up with hand plough at a distance of 60 cm each (row to row distance). Basal application of nutrients was made in these furrows at recommended rates and consisted of 60 kg N (half of total

Table 3. Sprouted tubers, sprout length and number of sprouts on tubers under various treatments

Treatment	Sprouted tubers (%)	Sprout length (mm)	Sprouts/ sprouted tuber
$P_1V_1S_1$	21.8	3.0	2.0
$P_1V_1S_2$	43.8	3.2	2.5
$P_1V_1S_3$	50.0	3.4	2.6
$P_1V_1S_4$	53.8	3.6	2.8
$P_1V_2S_1$	27.3	3.0	2.0
$P_1V_2S_2$	45.0	3.3	2.2
$P_1V_2S_3$	57.5	3.5	2.5
$P_1V_2S_4$	65.0	4.0	2.7
$P_2V_1S_1$	23.9	3.0	2.4
$P_2V_1S_2$	32.0	3.2	2.8
$P_2V_1S_3$	39.5	3.4	3.0
$P_2V_1S_4$	43.7	3.7	3.2
$P_2V_2S_1$	30.8	3.2	2.5
$P_2V_2S_2$	41.3	3.3	3.0
$P_2V_2S_3$	50.8	3.6	3.2
$P_2V_2S_4$	55.5	4.0	3.4

requirement), 80 kg P_2O_5 and 60 kg K_2O ha^{-1}. The fertilizers were then mixed thoroughly in the soil. Seed tubers were then placed in the furrows at a spacing of 20 cm. This was followed by application of well rotten animal manure @ 20 t ha^{-1}. The seed was covered by earthing up on both sides of row. Thus, the number of ridges in a subplot is equal to the number of planted rows, i.e. 8.

3.3.4 Irrigation

Irrigation was applied by furrow method in which water from the irrigation channel was diverted to the plot furrows formed on their own during the ridge formation over the planted rows. Due to heavy pressure on irrigation water supply system the crop could be irrigated only four times. On the other hand, normally 8-10 irrigations are needed for raising a good crop of potato under Palampur valley conditions. The first irrigation was applied on 7th March and last on 20th May. Remaining two irrigations were applied on 10th and 30th April. No irrigation was given after 20th May which encouraged proper tuber skin maturity and facilitated in the harvesting operation.

3.3.5 Earthing up and top dressing of nitrogen

The earthing up operation was done twice. First earthing up was done 60 days after P_1 planting and 55 days after P_2 planting. However, top dressing of N (60 kg/ha) was completed before the earthing up operation. Second earthing up was done about 25 days after the first earthing up.

3.3.6 Plant protection

The crop was given two protective sprays against potato tuber moth and late blight of potato at fortnightly intervals with first spray after 90 days in P_1 planting and 75 days in P_2 planting. The spray solutions were prepared by using 1.7 ml monocrotophos and 2 g of Dithane M-45/L water.

3.3.7 Harvesting

The potato crop was harvested at maturity. Produce from the net plot was kept separately for the purpose of recording total and grade wise tuber yield.

3.4 ADDITIONAL INFORMATION ABOUT EXPERIMENT

The potato crop in the experiment was infected by wilt disease. The severity of disease in various treatments was variable. The data on average number of plants infected by bacterial wilt is presented in Table 4.

Table 4. Incidence of bacterial wilt under various treatments.

Treatment	Number of plants infected by bacterial wilt (%)	Treatment	Number of plants infected by bacterial wilt(%)
$P_1V_1S_1$	65.8	$P_2V_1S_1$	48.8
$P_1V_1S_2$	63.3	$P_2V_1S_2$	23.3
$P_1V_1S_3$	43.9	$P_2V_1S_3$	13.3
$P_1V_1S_4$	0.0	$P_2V_1S_4$	5.3
$P_1V_2S_1$	53.3	$P_2V_2S_1$	37.2
$P_1V_2S_2$	16.9	$P_2V_2S_2$	23.0
$P_1V_2S_3$	14.2	$P_2V_2S_3$	13.3
$P_1V_2S_4$	10.9	$P_2V_2S_4$	2.8

3.5 OBSERVATIONS RECORDED

3.5.1 Per cent plant population

Total number of plants emerged in each net plot was counted at two stages viz., tuber initiation and harvest expressed in percentage.

3.5.2 Plant height

Five plants in each net plot were selected at random and tagged. Height of these tagged plants was measured in centimeters from the ground level to the highest tip. The fixed point adjacent to the ground level was kept constant by marking the mainshoot with the help of nonwashable ink. The height of five plants was taken and mean was worked out for statistical analysis. The plant height was recorded at stolonization, tuber initiation and harvest stage of the crop.

3.5.3 Number of stems/plant

Total number of stems were counted from five plants randomly tagged in the four central rows. Mean was then worked out and reported as number of stems/plant. The observation was recorded at three stages viz., stolonization, tuber initiation and at harvest.

3.5.4 Leaf area index (LAI)

The set of three plants which formed the basis of stolonization/tuber initiation(sections 3.5.6 and 3.5.7)was used for compution of LAI at these stages. One out of these three plants was selected at random and its leaf area measured (in cm^2) by using LI-COR Portable Leaf Area Meter. These leaves were then dried in a hot air oven at 70^{o}C till constant weight, their dry weight determined and relationship between unit leaf dry weight and leaf area worked out. Simultaneously the leaves of the two remaining uprooted plants were also detached, dried in oven and their dry weight was determined and converted into leaf area on the basis of above relationship. By simple summation technique, leaf area for three uprooted plants was computed and then converted to leaf area/plant. The latter was then converted into leaf area m^{-2} (in cm^{2}) by multiplying leaf area/plant by the plant population/m^{2} and finally represented as an index indicating leaf area/ground area.

3.5.5 Number of days taken for 75% emergence

Total number of plants per plot were counted starting from the day first plant emerged till 75% emergence at frequent intervals. When 75% plants emerged, the date was noted and total number of days required for emergence were computed from the date of planting.

3.5.6 Number of days taken for stolonization

On the day when 75% plants emerged in a plot, two plants were selected at random from the border area, uprooted and observed for appearance of stolons. If none of the plants bore a stolon, it indicated that the stage had not yet reached. In that case, the observation was repeated on alternate day(s). Conversely, if both plants bore stolons, the date was noted and days counted from planting to this date and denoted as days taken for stolonization. If only one of the two plants bore stolon(s) then another plant, again selected at random from border rows was observed for presence of stolon(s). The presence of stolon(s) on this plant indicated the appearance of the stage. However, if this plant, too, did not bear stolon, the observation was repeated on alternate day(s) till stolonization was recorded.

3.5.7 Number of days taken for tuber initiation

The procedure employed for recording tuber initiation was similar to the one adopted to record number of days taken for stolonization. The tuberization was considered to have initiated when the tip of the stolon had swollen to the grain size of gram.

3.5.8 Fresh weight of tubers/plant

The tubers from three plants harvested for recording number of tubers/plant were cleaned to remove the adherent soil and their fresh weight recorded. The fresh weight was divided by three and expressed as fresh weight of tubers per plant. This observation was recorded at 10 days interval commencing from 30th day of tuber initiation till harvest.

3.5.9 Dry weight of tubers/plant

After recording the fresh weight of tubers at each sampling time, tubers were cut into small pieces and air dried for 2 days. These air dried tuber pieces were then kept in hot air oven at 70^{o}C till constant weight. In case the fresh samples were too large, sub samples weighing 200-250g were drawn for oven drying and the total dry matter was calculated on the basis of this sub-sample. Mean was worked out by dividing total dry matter by three and expressed as dry weight of tubers/plant. This observation too, was recorded at 10 days interval commencing from 30th day of tuber initiation till harvest.

3.6 STUDIES AT HARVEST

3.6.1 Average tuber weight

The fresh weight of tubers of 3 plants recorded in section 3.5.8 was divided by total number of tubers and expressed as average tuber weight.

3.6.2 Tuber yield

The produce obtained from each net plot was cleaned and weighed and expressed in quintals per hectare.

3.6.3 Gradewise tuber yield

The produce of each net plot was graded into 4 grades on weight basis as below:

Grade	Tuber weight
A	$>$ 75 g
B	50-75 g
C	25-50 g
D	$<$ 25 g

Potato produce in each grade was weighed and converted to quintals per hectare.

3.7 POST HARVEST STUDIES

3.7.1 Tuber dry matter content

Fresh samples weighing about 200-250g from each plot were cut into small pieces and dried in a hot air oven at 70°C till constant weight. Dry weight of these samples was recorded and tuber dry matter content(%) then calculated as:

$$\text{Tuber dry matter content(\%)} = \frac{\text{Dry weight sample}}{\text{Fresh weight of sample}} \times 100$$

3.7.2 Tuber dry matter yield

The tuber yield/ha as computed in Section 3.6.2 was multiplied by dry matter content at harvest and expressed as tuber dry matter yield in quintals/ha.

3.7.3 Starch content

Starch content of the tubers was determined by Lane and Eynon (1923) Method. According to this method reducing sugars in potato tubers are first determined which are then converted into starch content as below:

Starch content(%) = % reducing sugars x 0.9

3.7.4 Protein content

For determination of protein content, N content in potato tubers was determined by employing Micro Kjeldahl method (AOAC, 1970). Protein content (%) was then estimated by multiplying % N by the factor 6.25 (Chopra and Kanwar, 1976).

3.7.5 Specific gravity

Specific gravity was determined adopting water displacement method in which a weighed potato tuber was immersed in known volume of water contained in 500 ml measuring cylinder. The resulting increase in volume was noted and the value utilized to work out the density of potato tubers as:

$$\underset{(\text{g cc}^{-1})}{\text{Density of potato tuber}} = \frac{\text{mass of potato tuber}}{\text{increase in volume of water}}$$

The specific gravity was then calculated as below:

$$\text{Specific gravity} = \frac{\text{Density of potato tuber}}{\text{Density of water at room temperature } (29^{o}C)}$$

3.8 STORAGE STUDIES

The freshly harvested produce from each net plot weighing about three to four kg was put in bamboo baskets which were stored in an ordinary room in a *katcha* building for a period of ninety days. The initial weight as well as number of tubers were recorded separately and observations on following parameters were computed regularly at an interval of 10 days. The last observation was recorded on 90th day of storage.

3.8.1 Cumulative moisture loss

The moisture loss from potato tubers was first calculated as:

$$\text{Moisture loss(\%)} = \frac{\text{Weight of tubers at the beginning of interval} - \text{Weight of tubers at the end of interval}}{\text{Weight of tubers at the beginning of interval}} \times 100$$

The cumulative moisture loss (%) was then worked out by summation of moisture losses at different intervals of time.

3.8.2 Cumulative rottage

The rottage (%) was first calculated as:

$$\text{Rottage(\%)} = \frac{\text{Weight of rotten tubers at the end of interval}}{\text{Weight of tubers at the beginning of interval}} \times 100$$

The cumulative rottage (%) was then worked out by summation of rottage (%) at different intervals of time.

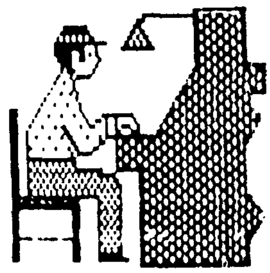
3.8.3 Sprouting percentage

The sprouting percentage was calculated as:

$$\text{Sprouting}(\%) = \frac{\text{Number of tubers with sprouts}}{\text{Total number of tubers}} \times 100$$

3.9 STATISTICAL ANALYSIS

The data thus obtained were subjected to statistical analysis as per procedure for a split plot design (Gomez and Gomez, 1984). The data on storage aspects were subjected to square root transformation before subjecting to statistical analysis. The critical difference values were computed at 5% level of significance for comparison of treatment means.



EXPERIMENTAL RESULTS

4. EXPERIMENTAL RESULTS

The effect of experimental treatments viz., duration of sprouting, date of planting and cultivars on plant growth and development, tuber yield and quality as well as storage behaviour of potato was studied during spring 1993 and the results obtained have been presented in this chapter.

4.1 GROWTH AND DEVELOPMENT STUDIES

The data in respect of various growth parameters viz., per cent plant population, plant height, stems per plant, and leaf area index as affected by various treatments have been presented in Tables 5 and 7 and their analyses of variance have been presented in Appendix II. The treatments effects on plant height and leaf area index have also been depicted in Figures 4 and 5, respectively.

4.1.1 Per cent plant population

The duration of sprouting influenced the per cent plant population significantly at both stages of observation (Table 5). The value of this parameter was significantly higher in 45 days (S_4) and 30 days (S_3) sprouting duration treatments than 15 days duration(S_2) as well control (S_1) at tuber initiation as well as harvest stages. However, the former two treatments (S_4 and S_3) as well as the latter two (S_2 and S_1) behaved statistically alike between themselves.

The effect of date of planting as well as cultivars on plant population was not significant at any of the stages of observation.

4.1.2 Plant height

The plant height was influenced significantly by various treatments at all the three stages of observation (Table 5). The plant height was significantly higher in control (S_1) compared to 15,30 or 45 days sprouting duration treatments at stolonization, tuber initiation as well as harvest stages. The latter two sprouting duration treatments viz., 30 days and 45 days recorded lowest plant height and remained statistically alike at all stages of observation.

Planting dates as well as potato cultivars differed significantly between themselves at tuber initiation and harvest stages. Mean plant height of 47.3 cm recorded in P_2 at harvest stage was significantly higher than 36.1 cm recorded in P_1 planting. Similar trend in plant height was observed at tuber initiation stage. The plant height of cultivar QB/A-9-120 was significantly higher than Kufri Jyoti at both the stages.

The interaction effect between sprouting duration and cultivars influenced the plant height significantly at stolonization, tuber initiation and harvest stages (Table 6). The plant height of QB/A-9-120 (V_1) decreased significantly and consistently with increase in duration of sprouting from S_1 to S_4. Similar trend was recorded in Kufri Jyoti except that the decrease was significant only upto 30 days sprouting duration. Comparison of the two cultivars at a given duration of sprouting indicated that QB/A-9-120 had

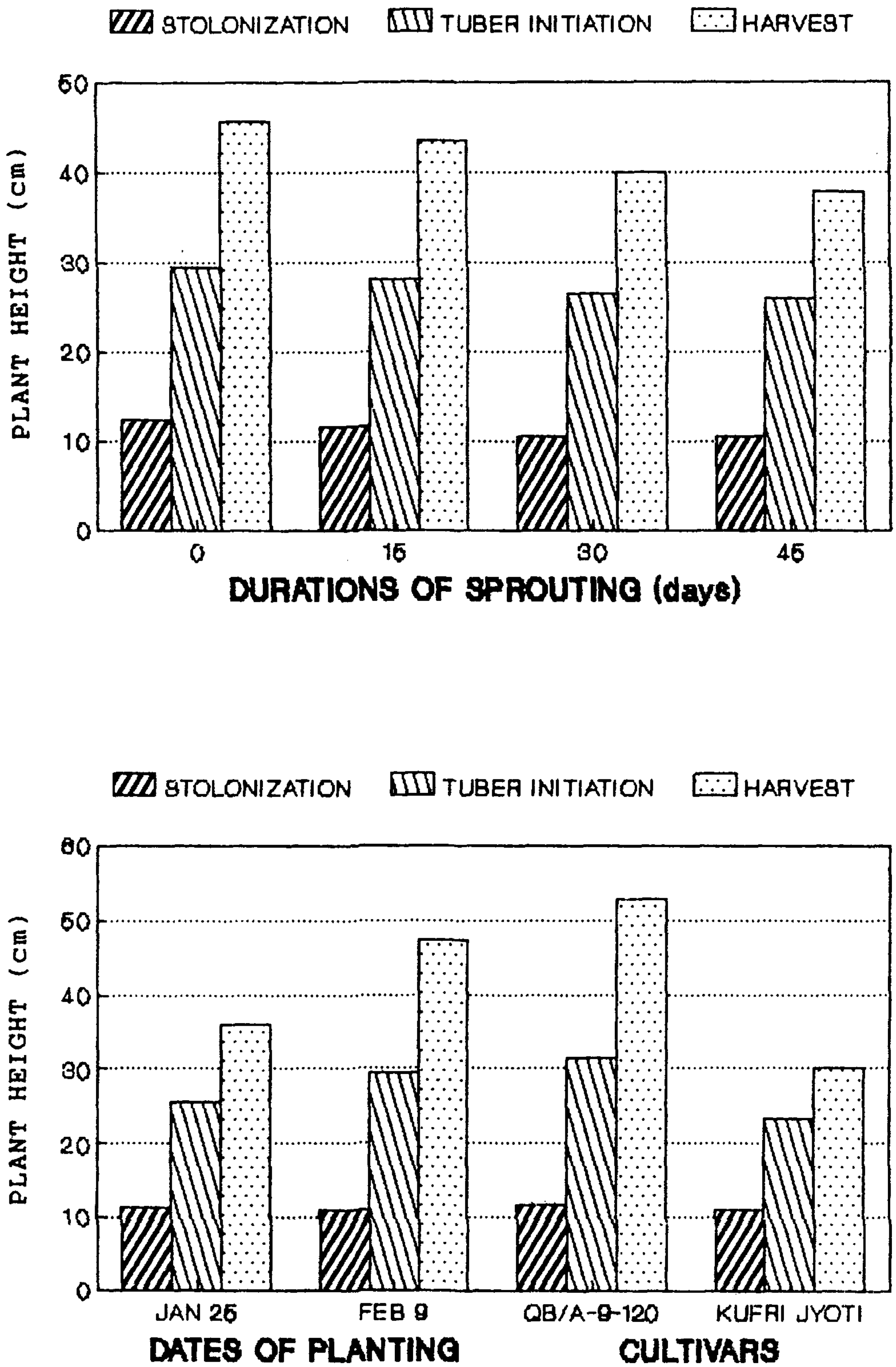


FIG.4 EFFECT OF SPROUTING DURATIONS, PLANTING DATES AND CULTIVARS ON PLANT HEIGHT (cm)

Table 5. Effect of duration of sprouting, date of planting and cultivar on plant population and plant height

Treatment	Plant population (%)		Plant height (cm)		
	Tuber initiation	Harvest	Stoloni-zation	Tuber initiation	Harvest
Duration of sprouting (days)					
0	92.1	86.9	12.4	29.5	45.6
15	93.1	89.8	11.5	28.1	43.4
30	94.5	93.7	10.6	26.6	39.9
45	94.7	94.1	10.4	26.0	37.8
S.Em±	0.42	0.47	0.15	0.33	0.79
CD at 5%	1.23	1.38	0.45	0.96	2.30
CV (%)	1.56	1.80	6.83	4.12	6.56
Date of planting					
January 25	93.1	90.9	11.4	25.6	36.1
February 9	94.0	91.7	11.0	29.5	47.3
S.Em±	0.27	0.26	0.19	0.74	1.78
CD at 5%	NS	NS	NS	2.56	6.18
CV (%)	1.41	1.42	11.96	13.19	21.01
Cultivar					
QB/A-9-120	93.5	90.3	11.5	31.4	53.0
Kufri Jyoti	93.7	91.9	11.0	23.7	30.3
S.Em±	0.27	0.26	0.19	0.74	1.78
CD at 5%	NS	NS	NS	2.56	6.18
CV (%)	1.41	1.42	11.96	13.19	21.01

NS - Not significant

significantly taller plants than Kufri Jyoti when the seed tubers were given either no treatment (S_1) or a sprouting treatment of 30 days. The varieties did not differ between themselves when sprouted for 15 or 45 days.

Table 6. Interaction effect between durations of sprouting and cultivars on plant height (cm)

Duration of sprouting (days)	Cultivar					
	V_1	V_2	V_1	V_2	V_1	V_2
	Stolonization		Tuber initiation		Harvest	
0	12.8	11.9	33.5	25.5	57.9	33.4
15	11.8	11.2	31.9	24.3	55.1	31.8
30	11.1	10.2	31.3	21.9	52.2	27.6
45	10.1	10.7	29.1	23.0	47.0	28.6

Comparisons

	Stolonization	Tuber initiation	Harvest
1. Two sprouting durations at the same cultivar:			
a. S.Em±	0.22	0.46	1.12
b. CD at 5%	0.65	1.36	3.26
2. Two cultivars at the same or different duration(s) of sprouting:			
a. S.Em±	0.27	0.84	2.03
b. CD at 5%	0.85	2.80	6.76

4.1.3 Number of stems/plant

The duration of sprouting influenced the number of stems produced by each plant significantly at all the stages of observation (Table 7). The number of stems was significantly higher in 45 days (S_4) and 30 days (S_3) sprouting duration treatments than 15 days duration (S_2) as well as control (S_1) at stolonization, tuber initiation and harvest stages. The former two treatments (S_4 and S_3) as well as the latter two, however, behaved statistically alike among themselves.

Table 7. Effect of duration of sprouting, date of planting and cultivar on stems/plant and leaf area index

Treatment	Stems/plant			Leaf area index		
	Stoloni-zation	Tuber initiation	Harvest	Stoloni-zation	Tuber initiation	Harvest
Duration of sprouting (days)						
0	1.4	1.6	1.8	0.35	1.07	0.77
15	1.5	1.8	1.9	0.39	1.17	0.87
30	1.7	2.0	2.1	0.44	1.32	1.01
45	1.7	2.0	2.0	0.45	1.35	1.35
S.Em±	0.05	0.04	0.04	0.01	0.02	0.04
CD at 5%	0.16	0.12	0.11	0.04	0.06	0.12
CV (%)	12.07	7.76	6.74	7.21	5.23	14.61
Date of planting						
January 25	1.6	1.8	1.9	0.40	1.02	0.85
February 9	1.5	1.9	2.0	0.42	1.43	1.15
S.Em±	0.03	0.06	0.05	0.04	0.04	0.02
CD at 5%	NS	NS	NS	NS	0.15	0.08
CV (%)	10.34	16.67	13.78	19.13	16.93	11.51
Cultivar						
QB/A-9-120	1.6	1.9	2.0	0.41	1.57	1.13
Kufri Jyoti	1.5	1.8	1.9	0.40	0.88	0.87
S.Em±	0.03	0.06	0.05	0.04	0.04	0.02
CD at 5%	NS	NS	NS	NS	0.15	0.08
CV (%)	10.34	16.67	13.78	9.56	16.93	11.51

NS - Not significant

The effect of date of planting on number of stems per plant was not significant at all stages of observation. Likewise, the two cultivars were statistically at par in this respect.

4.1.4 Leaf area index (LAI)

The duration of sprouting influenced the crop leaf area index significantly at all the three stages of observation (Table 7). The LAI in 45 days sprouting duration was significantly higher but at par with 30 days sprouting duration at all stages of observation. Significantly lowest LAI was recorded in control (S_1) which however, remained at par with 15 days sprouting duration treatment except at tuber initiation stage.

In respect of date of planting and cultivars, significant differences were observed at tuber initiation and harvest stages, only (Fig.5). In general, LAI increased from stolonization stage to tuber initiation stage and then declined at harvest stage. In P_2 planting significantly higher LAI was recorded at tuber initiation and harvest stages as compared to P_1 date of planting (Table 7). Similarly, the value of LAI in QB/A-9-120 was significantly higher than in Kufri Jyoti at tuber initiation as well as at harvest.

Interaction between duration of sprouting (S) and cultivars (V) was found significant at all stages of observation. Since, a higher order interaction between duration of sprouting, date of planting and cultivars was

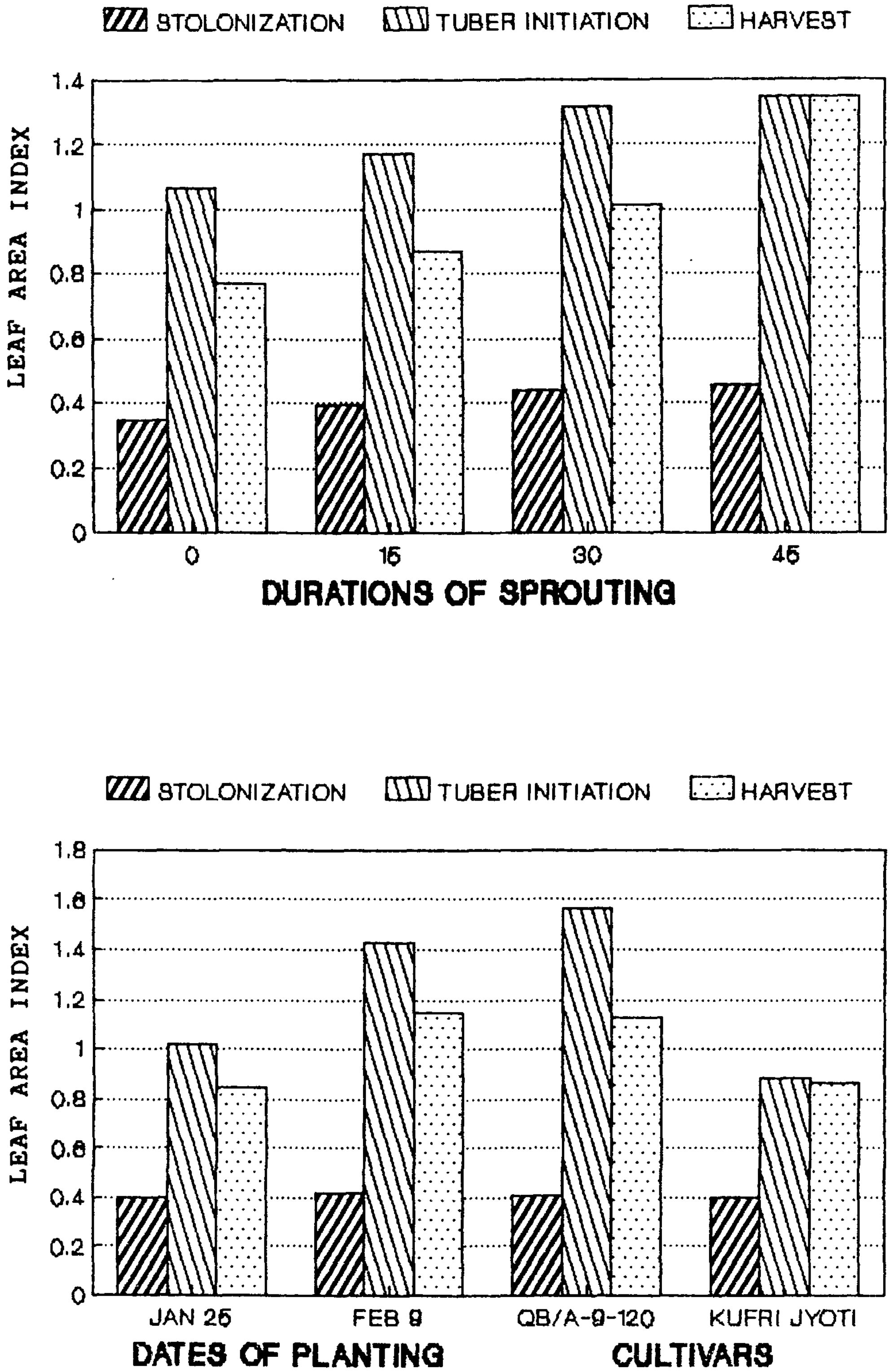


FIG.5 EFFECT OF SPROUTING DURATIONS, PLANTING DATES AND CULTIVARS ON LEAF AREA INDEX

also found significant at tuber initiation stage, the description of lower order interaction between duration of sprouting and cultivars at this stage (tuber initiation) has been omitted.

At stolonization stage, the LAI in Kufri Jyoti decreased significantly and consistently from S_3 (30 days) to S (control) (Table 8), treatment S_4 (45 days), however, remained at par with S_3. In QB/A-9-120, highest LAI was recorded in S_4 (45 days) which again decreased significantly and consistently with each reduction in duration of sprouting. The two cultivars did not differ significantly between themselves at any given duration of sprouting except S_4 when QB/A-9-120 recorded higher LAI than Kufri Jyoti.

Table 8. Interaction effect between durations of sprouting and cultivars on leaf area index

Duration of sprouting (days)	Cultivar			
	V_1	V_2	V_1	V_2
	Stolonization		Harvest	
0	0.35	0.35	1.37	0.78
15	0.40	0.39	1.48	0.85
30	0.43	0.44	1.65	0.98
45	0.48	0.42	1.76	0.93

Comparisons

	Stolonization	Harvest
1. Two sprouting durations at the same cultivar:		
a. S.Em±	0.01	0.06
b. CD at 5%	0.02	0.18
2. Two cultivars at the same or different duration(s) of sprouting:	0.02	0.08
a. S.Em±	0.05	0.23
b. CD at 5%		

At harvest stage also the LAI in Kufri Jyoti was significantly higher in 30 days (S_3) sprouting duration and lower in control (S_1) than other treatments, however, S_2, S_4 and S_3 and S_1, S_2 and S_4 behaved statistically alike. In QB/A-9-120, 45 days sprouting duration remaining at par with 30 days resulted in significantly higher LAI than control (S_1). The latter, however, remained at par with 15 days sprouting duration. Values of LAI were significantly higher in QB/A-9-120 than Kufri Jyoti at a given duration of sprouting treatment.

As mentioned earlier, interaction effect between duration of sprouting, date of planting and cultivars was observed to be significant at tuber initiation stage (Table 9). Under both dates of planting in variety Kufri Jyoti significantly highest LAI was recorded when seed tubers were sprouted for 30 days, however, this treatment remained at par with 45 days sprouting duration. Similarly, irrespective of the date of planting significantly lowest LAI values of Kufri Jyoti were recorded when seed tubers were used without pre sprouting (S_1). However, the difference between control (S_1) and 15 days sprouting duration (S_2) was not significant when crop was planted on first date (P_1). Cultivar QB/A-9-120 planted either on P_1 or P_2 date of planting, produced significantly highest LAI in 45 days sprouting duration treatment (S_4). However, the difference between S_4 and S_3 in P_1 planting was not significant. As in Kufri Jyoti, lowest LAI in QB/A-9-120 was recorded in S_1 treatment. Comparison of planting dates for each of the two cultivars indicated that the LAI increased significantly from P_1 to P_2 but the differences between two dates were not significant in Kufri Jyoti in control and 30 days duration treatments.

Table 9. Interaction effect between durations of sprouting, dates of planting and cultivars on leaf area index at tuber initiation stage

Duration of sprouting (days)	QB/A-9-120		Kufri Jyoti	
	P_1	P_2	P_1	P_2
0	1.08	1.67	0.74	0.82
15	1.19	1.79	0.78	0.92
30	1.26	2.06	0.92	1.04
45	1.32	2.21	0.86	1.00

Comparisons

1. Two sprouting durations at the same PxV combination:
   a. S.Em± 0.03
   b. CD at 5% 0.08
2. Two PxV combinations at the same or different duration(s) of sprouting:
   a. S.Em± 0.04
   b. CD at 5% 0.13

4.2 DAYS TAKEN TO DIFFERENT PHENOLOGICAL STAGES

The data on the effect of various treatments on number of days taken to attain various phenological stages viz., 75 per cent emergence, stolonization and tuber initiation have been presented in Table 10 and shown graphically in Fig.6. The corresponding analyses of variance have been given in Appendix III.

The effect of duration of sprouting was found significant on the number of days required to reach various phenological stages and similar trend was observed at all these stages (Fig.6). Treatment S_4 (45 days) took

Table 10. Effect of duration of sprouting, date of planting and cultivar on attainment of phenological stages by potato

Treatment	Days taken for		
	Emergence (75%)	Stolonization	Tuber initiation
Duration of sprouting (days)			
0	46.2	54.5	65.4
15	44.0	52.2	63.4
30	41.3	49.4	60.9
45	41.7	49.2	60.8
S.Em±	0.19	0.11	0.15
CD at 5%	0.57	0.34	0.45
CV (%)	1.15	0.79	0.85
Date of planting			
January 25	43.8	51.8	64.1
February 9	42.7	50.8	61.1
S.Em±	0.19	0.25	0.29
CD at 5%	0.65	0.37	1.02
CV (%)	2.57	2.41	2.30
Cultivar			
QB/A-9-120	45.1	52.6	67.4
Kufri Jyoti	41.5	50.0	57.8
S.Em±	0.19	0.25	0.29
CD at 5%	0.65	0.87	1.02
CV (%)	2.57	2.41	2.30

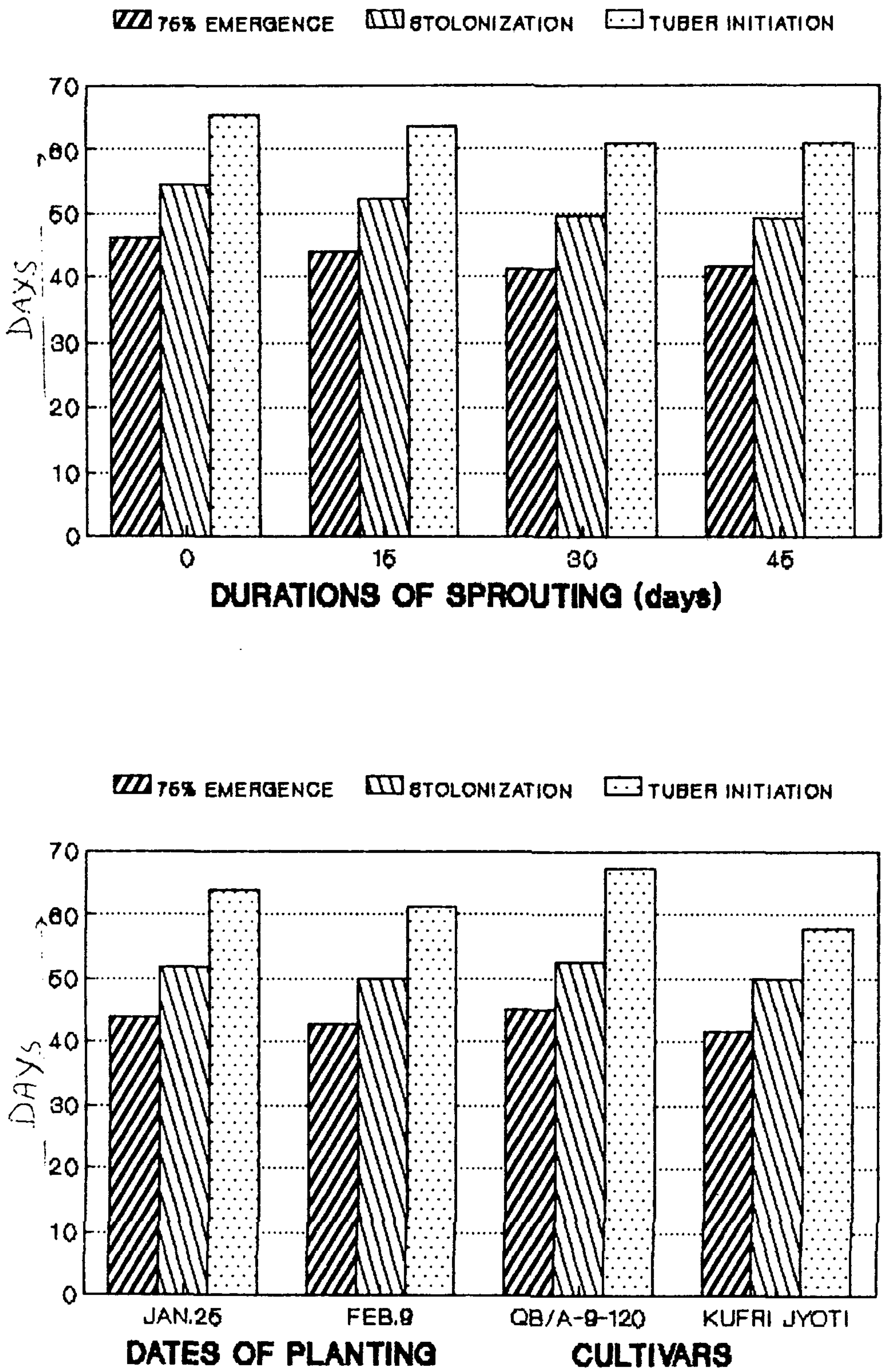


FIG.6 EFFECT OF SPROUTING DURATIONS, PLANTING DATES AND CULTIVARS ON ATTAINMENT OF PHENOLOGICAL STAGES BY POTATO

significantly lesser time to attain 75 per cent emergence, stolonization as well as tuber initiation and remained at par with S_3 (30 days). Significantly longer time was taken by S_1 (control) and was followed by S_2 in this regard. The difference between S_1 and S_4 for plant emergence (75%), stolonization and tuber initiation stages was 4.5, 5.3 and 4.6 days, respectively.

As regards the effect of planting dates, the attainment of all these phenological stages was significantly earlier in P_2 as compared to P_1 planting. The difference between P_1 and P_2, however, ranged from 1 to 3 days at various stages. In respect of cultivars, the attainment of different phenological stages was significantly earlier in Kufri Jyoti as compared to QB/A-9-120, the difference between the two cultivars being 9.6 days at tuber initiation stage.

The effect of interaction between duration of sprouting and cultivars on days taken for reaching 75 per cent emergence and tuber initiation stages was found to be significant (Table 11). In Kufri Jyoti, both phenological stages were recorded significantly earlier in S_3 followed by S_4 treatment. Significantly maximum duration was required for these stages by Kufri Jyoti when it was raised from unsprouted seed tubers (S_1). In respect of days taken for 75 per cent emergence by this variety, S_2 and S_4 remained statistically at par whereas, for tuber initiation the former (S_2) took significantly longer duration than the latter (S_4).

In QB/A-9-120, time taken for 75 per cent emergence as well as tuber initiation decreased significantly and consistently with increase in the duration of sprouting from S_1 and S_4, the difference between the maximum and the minimum durations being 6.6 and 6.7 days, respectively. Comparison of cultivars at any fixed duration of sprouting indicated that QB/A-9-120 took significantly longer time than Kufri Jyoti for attainment of 75 per cent emergence as well as tuber initiation except that the difference between the two in respect of plant emergence was not significant at 45 days sprouting duration.

Table 11. Interaction effect between durations of sprouting and cultivars on days taken for attainment of phenological stages by potato

Duration of sprouting (days)	Cultivar			
	V_1	V_2	V_1	V_2
	Emergence (75%)		Tuber initiation	
0	48.3	44.2	70.7	60.2
15	46.3	41.7	68.7	58.2
30	44.2	38.5	66.3	55.5
45	41.7	41.7	64.0	57.5

Comparisons

1. Two sprouting durations at the same cultivar:
   a. S.Em± 0.27 0.22
   b. CD at 5% 0.79 0.64
2. Two cultivars at the same or different duration(s) of sprouting:
   a. S.Em± 0.30 0.35
   b. CD at 5% 0.95 1.13

The interaction effect between duration of sprouting, date of planting and cultivars was found significant at stolonization stage (Table 12). It was observed that irrespective of the date of planting, stolonization stage in Kufri Jyoti took significantly lesser time when seed tubers were given a sprouting treatment for 30 days. Time taken for stolonization in other treatments was in the order $S_4<S_2<S_1$. In cultivar QB/A-9-120 planted on either date, the time taken for this stage decreased significantly and consistently with increase in sprouting duration from S_1 to S_4. Further, the delayed planting (P_2) resulted in significantly earlier stolonization at all durations of sprouting except that the stage took statistically same time in QB/A-9-120 when seed tubers were planted after sprouting for 30 or 45 days.

Table 12. Interaction effect between durations of sprouting, dates of planting and cultivars on days taken for stolonization stage

Duration of sprouting (days)	QB/A-9-120		Kufri Jyoti	
	P_1	P_2	P_1	P_2
0	57.3	55.7	53.3	51.7
15	54.3	52.7	51.3	50.3
30	51.3	51.3	48.3	46.7
45	49.0	49.7	49.7	48.7

Comparisons

1. Two sprouting durations at the same PxV combination:
   a. S.Em± 0.23
   b. CD at 5% 0.68
2. Two PxV combinations at the same or different duration(s) of sprouting:
   a. S.Em± 0.29
   b. CD at 5% 0.93

4.3 TUBER DEVELOPMENT

The data on various aspects of tuber development viz., number of tubers/plant and fresh and dry weight of tubers/plant as influenced by the experimental factors viz., duration of sprouting, date of planting and cultivars in respect of different observations have been presented in Table 13. The analyses of variance have been given in Appendix IV. The first observation on different aspects of tuber development was recorded on 30th day of tuber initiation with subsequent observations at 10 days interval till harvest. Because of 15 days delay in planting in P_2 over P_1 and late tuberization (by approximately 10 days, Table 10) in QB/A-9-120 compared with Kufri Jyoti, the number of days taken from tuber initiation stage upto harvest in different treatments was not similar (crop in all treatments harvested on 12 june, 1993). Thus, only 3 observations could be recorded in respect of each experimental treatment (excluding the observation at harvest stage and which has been described in section 4.4 pertaining to yield attributes). The minimum number of observations (3) was recorded in respect of QB/A-9-120 planted on second date (9th February) whereas, in some treatments viz., Kufri Jyoti planted on first date (25th January), a maximum of 5 observations were recorded.

Since, data in respect of certain treatments was not available in respect of last two observation, this data (4th and 5th observation) were not subjected to statistical analyses and have been presented seperately in Table 16.

4.3.1 Number of tubers/plant

The effect of duration of sprouting on tuber number/plant was significant at all stages of observation (Table 13). Significantly higher number of tubers/plant was recorded in S_4 which, however, remained at par with S_3 treatment. The number of tubers in S_2 was lower than S_3 and S_4. Significantly lowest tuber number was observed in S_1 treatment.

The effect of date of planting on tuber number/plant was not significant at all the stages of observation. Between cultivars, significantly higher number of tubers/plant was recorded in Kufri Jyoti compared with QB/A-9-120.

The number of tubers per plant was influenced significantly by interaction between duration of sprouting and cultivars at all stages of observation (Table 14). In QB/A-9-120, significant and consistent increase in tuber number was observed with increase in duration of sprouting from S_1 to S_4 treatments. Similar trend was observed in Kufri Jyoti except the increase in tuber number was observed upto S_3 treatment. The number of tubers in S_4 was significantly lower than S_3 in this variety. When comparison of cultivars was made at a given duration of sprouting, Kufri Jyoti recorded significantly higher tuber number than QB/A-9-120 at S_1, S_2 and S_3 sprouting durations. However at S_4, the difference between the two cultivars was not significant.

Table 13. Effect of duration of sprouting,date of planting and cultivar on tuber development

Treatment	Tubers/plant			Tubers fresh weight/ plant (g)			Tubers dry weight/ plant (g)		
	Day of tuber initiation								
	30th	40th	50th	30th	40th	50th	30th	40th	50th
Duration of sprouting (days)									
0	2.9	3.4	4.4	61.7	85.7	107.9	10.2	14.4	19.0
15	3.6	4.1	5.4	78.5	106.4	134.0	13.1	18.2	23.3
30	4.7	5.7	6.8	110.3	146.5	168.5	18.6	25.3	29.8
45	4.8	5.9	7.2	112.2	146.8	172.4	18.6	25.4	30.2
S.Em±	0.08	0.11	0.09	1.51	2.03	2.42	0.27	0.32	0.47
CD at 5%	0.25	0.31	0.27	4.40	5.93	7.06	0.78	0.94	1.37
CV (%)	7.50	7.74	5.31	5.76	5.80	5.75	6.17	5.34	6.38
Date of planting									
January 25	4.2	4.7	5.7	99.1	126.8	154.0	16.6	21.7	27.1
February 9	3.8	4.9	6.1	82.2	115.9	137.4	13.7	19.9	24.1
S.Em±	0.23	2.14	0.20	1.40	2.91	3.94	0.25	0.62	0.50
CD at 5%	NS	NS	NS	4.87	10.08	10.17	0.88	2.14	1.72
CV (%)	17.47	14.33	16.71	7.60	11.75	9.88	8.24	14.57	9.51
Cultivar									
QB/A-9-120	3.5	4.2	4.9	64.2	89.4	104.2	10.6	15.3	18.2
Kufri Jyoti	4.5	5.4	6.9	117.2	153.3	187.2	19.6	26.3	32.9
S.Em±	0.23	0.14	0.20	1.40	2.91	2.94	0.25	0.62	0.50
CD at 5%	0.78	0.48	0.70	4.87	10.88	10.17	0.88	2.14	1.72
CV (%)	17.47	14.33	16.71	7.60	11.75	9.88	8.24	14.57	9.51

NS - Not significant

In respect of observation on 60th day of tuber initiation (4th observation), the number of tubers produced by QB/A-9-120 planted on first date increased consistently with increase in duration of sprouting from S_1 to S_4 (Table 16). In Kufri Jyoti, planted on first date, maximum tubers per plant were recorded in S_3 followed by S_4 duration of sprouting. Minimum tubers per plant were recorded in S_1. Comparison of Kufri Jyoti at a given duration of sprouting revealed that number of tubers recorded in P_2 planting was higher compared to P_1 planting. Fifth observation on number of tubers per plant was recorded only in Kufri Jyoti planted on first date (25th January), where S_3 sprouting duration recorded higher tuber number. Tuber number was minimum in no sprouting (S_1) treatment.

4.3.2 Fresh and dry weights of tubers/plant

Forty five and 30 days sprouting durations remaining at par with each other resulted in significantly higher fresh weight of tubers per plant than 15 days sprouting duration at all the stages of observation (Table 13). The trend in respect of dry weight of tubers/plant was similar to that observed in fresh weight of tubers at all stages of observation.

The effect of date of planting and cultivars on fresh and dry weights of tubers was significant. Fresh and dry weights of tubers per plant were significantly higher in first date of planting (25th January) than second date of planting (9th February). Between cultivars, the values of these parameters were significantly higher in Kufri Jyoti compared with QB/A-9-120.

Table 14. Interaction effect between durations of sprouting and cultivars on tuber development

Duration of sprouting (days)	Cultivar					
	V_1	V_2	V_1	V_2	V_1	V_2
	I*		II		III	
A. Tubers/plant						
0	2.5	3.4	2.8	4.1	3.3	5.4
15	3.1	4.2	3.4	4.9	4.2	6.6
30	3.8	5.6	4.5	6.8	5.3	8.3
45	4.7	4.9	6.1	5.8	6.8	7.3
Comparisons						
1. Two sprouting durations at the same cultivar:						
a. S.Em±	0.12		0.15		0.13	
b. CD at 5%	0.36		0.45		0.38	
2. Two cultivars at the same or different duration(s) of sprouting;						
a. S.Em±	0.17		0.19		0.23	
b. CD at 5%	0.59		0.61		0.77	
B. Tubers fresh weight /plant (g)						
0	37.2	86.1	53.3	118.1	65.0	150.8
15	48.1	108.9	71.7	141.1	88.6	179.4
30	75.0	145.6	103.9	189.2	116.4	220.6
45	96.4	128.1	128.6	165.0	146.8	198.1
Comparisons						
1. Two sprouting durations at the same cultivar:						
a. S.Em±	2.13		2.87		3.42	
b. CD at 5%	6.23		8.39		9.99	
2. Two cultivars at the same or different durations(s) of sprouting:						
a. S.Em±	2.23		3.83		4.17	
b. CD at 5%	6.90		12.34		13.30	
C. Tubers dry weight/plant (g)						
0	6.2	14.3	9.0	19.9	11.3	26.6
15	8.1	18.2	12.1	24.2	15.3	31.2
30	12.6	24.6	17.9	32.7	20.6	39.0
45	15.7	21.5	22.2	28.6	25.7	34.8
Comparisons						
1. Two sprouting durations at the same cultivar:						
a. S.Em±	0.38		0.79		0.66	
b. CD at 5%	1.11		2.29		1.93	
2. Two cultivars at the same or different duration(s) of sprouting;						
a. S.Em±	0.42		0.73		0.76	
b. CD at 5%	1.30		2.19		2.38	

* I, II and III represent observation recorded on 30th, 40th and 50th day of tuber initiation, respectively.

The interaction effect between duration of sprouting and cultivars on fresh as well as dry weight of tubers/plant was found to be significant at all the stages of observation (Table 14). In cultivar QB/A-9-120, fresh and dry weights increased significantly and consistently with increase in duration of sprouting from control (S_1) to 45 days sprouting duration (S_4). In respect of Kufri Jyoti, different sprouting durations ranked in order $S_3>S_4>S_2>S_1$.

The interaction effect between dates of planting and cultivars in respect of fresh as well as dry weights of tubers were also found significant at all the stages of observation (Table 15). The tuber fresh weight/plant in QB/A-9-120 decreased with delay in planting from 25th January to 9th February. However, in Kufri Jyoti, recorded significantly higher tuber fresh weight than in respect of first two observations. However, the two dates did not differ significantly in this respect on 3rd observation. Further, irrespective of date of planting, the variety Kufri Jyoti recorded significantly higher tuber fresh weight/plant at all the stages of observation.

Almost similar trend was observed in respect of tuber dry weight/plant at all the stages of observation.

In 4th observation, fresh as well as dry weight of tubers/plant in QB/A-9-120 increased consistently with increase in duration of sprouting from S_1 to S_4 (Table 16). Irrespective of date of planting, the values of fresh and dry weights/plant in Kufri Jyoti were higher in S_3 sprouting duration. Further, the lowest fresh and dry weights were

Table 15. Interaction effect between dates of planting and cultivars on tuber development

Date of planting	Cultivar					
	V_1	V_2	V_1	V_2	V_1	V_2
	I		II		III	
	A. Tubers fresh weight/plant (g)					
P_1	89.2	109.0	110.6	143.1	125.6	182.5
P_2	39.2	125.3	68.2	163.6	82.8	192.0
S.Em±	1.99		4.12		4.15	
CD at 5%	6.87		14.25		14.38	
	B. Tubers dry weight/plant (g)					
P_1	14.9	18.3	18.9	24.5	21.9	32.2
P_2	6.3	21.0	11.9	28.2	14.6	33.6
S.Em±	0.36		0.87		0.70	
CD at 5%	1.25		3.03		2.43	

* I, II and III represent observation recorded on 30th, 40th and 50th day of tuber initiation, respectively.

Table 16. Interaction effect between durations of sprouting, dates of planting and cultivars on tuber development

Duration of sprouting (days)	Date of planting x cultivar			
	P_1V_1	P_1V_2	P_2V_2	P_1V_2
	I*			II
	A. Tubers/plant			
0	4.2	6.0	7.3	5.8
15	5.1	7.3	8.3	7.1
30	6.1	8.2	9.5	8.3
45	7.6	8.0	8.3	7.8
	B. Tubers fresh weight/plant (g)			
0	91.7	174.4	168.3	180.6
15	121.7	200.0	192.8	203.3
30	145.6	241.1	233.3	245.6
45	175.6	217.8	211.1	222.2
	C. Tubers weight/plant (g)			
0	16.2	30.7	29.8	32.6
15	21.7	35.7	34.3	37.0
30	26.2	43.8	42.5	45.2
45	32.3	39.2	38.0	41.3

*I and II represent observation recorded on 60th and 70th day of tuber initiation, respectively.

recorded in S_1 treatment. Similar trend in respect of Kufri Jyoti was recorded in 5th observation.

4.4 YIELD ATTRIBUTES

The data pertaining to the effect of experimental treatments on various yield attributes viz., average tuber weight, number of tubers per plant and fresh and dry weights of tubers per plant have been presented in Table 17. The corresponding analyses of variance have been given in Appendix V.

4.4.1 Average tuber weight

The effect of duration of sprouting on average tuber weight was not significant whereas, the parameter was influenced significantly by date of planting as well as cultivars (Table 17). Planting on first date (P_1) recorded significantly higher tuber weight compared with P_2 planting. The average tuber weight of Kufri Jyoti was significantly higher than QB/A-9-120.

4.4.2 Number of tubers per plant

The duration of sprouting influenced the number of tubers produced by each plant significantly (Table 17). The number of tubers was significantly higher in 45 days (S_4) followed by 30 days (S_3) and 15 days (S_2) sprouting durations. The lowest number of tubers was recorded in control treatment (S_1).

The effect of date of planting on number of tubers per plant was not significant. However, the effect of cultivars was significant and Kufri Jyoti produced significantly higher number of tubers per plant than QB/A-9-120.

Table 17. Effect of duration of sprouting, date of planting and cultivar on yield attributes

Treatment	Average tuber weight (g)	Tubers/ plant	Tubers fresh weight/plant (g)	Tubers dry weight/ plant(g)
Duration of sprouting (days)				
0	22.6	5.4	126.7	23.6
15	24.1	6.3	156.5	29.0
30	24.4	7.5	188.5	35.1
45	0.50	0.12	2.60	0.47
S.Em±	0.50	0.12	2.60	0.47
CD at 5%	NS	0.35	7.64	1.39
CV (%)	7.34	8.70	7.70	5.38
Date of planting				
January 25	24.9	6.9	174.2	32.2
February 9	22.7	6.7	157.2	29.4
S.Em±	0.48	0.18	2.23	0.40
CD at 5%	1.67	NS	7.71	1.40
CV (%)	9.99	18.3	9.30	6.43
Cultivar				
QB/A-9-120	21.2	5.4	115.3	21.5
Kufri Jyoti	26.4	8.2	216.1	40.1
S.Em±	0.48	0.18	2.23	0.40
CD at 5%	1.67	0.62	7.71	1.40
CV (%)	9.99	18.30	9.30	6.43

NS - Not significant

The interaction effect between sprouting duration and cultivars influenced the number of tubers per plant significantly (Table 18). The number of tubers per plant of QB/A-9-120 (V_1) increased significantly and consistently with increase in duration of sprouting from S_1 to S_4. Similar trend was recorded in Kufri Jyoti except that the increase was significant upto S_3 followed by S_4 sprouting duration treatment. Comparison of two cultivars at a given duration of sprouting indicated that for all the durations of sprouting, Kufri Jyoti produced significantly higher number of tubers per plant than QB/A-9-120.

4.4.3 Fresh and dry weights of tubers per plant

The duration of sprouting influenced significantly the fresh as well as dry weight of tubers produced by each plant (Table 17). Significantly higher tuber fresh weight was recorded in 45 days sprouting duration (S_4). However, this treatment was at par with 30 days (S_3) sprouting duration treatment but, significantly superior to 15 days (S_2) as well as no sprouting (S_1) treatment. The lowest fresh weight was recorded in S_1. Similar trend was observed in respect of tuber dry matter production.

The effect of date of planting as well as cultivars on fresh and dry weight of tubers was found to be significant (Table 17). First date of planting (P_1) produced significantly higher fresh weight of tubers per plant as compared to second date of planting (P_2). Between cultivars, Kufri Jyoti recorded significantly higher fresh as

Table 18. Interaction effect between durations of sprouting and cultivars on yield attributes

Duration of sprouting (days)	Cultivar					
	V_1	V_2	V_1	V_2	V_1	V_2
	Tubers/plant		Tubers fresh weight/plant (g)		Tubers weight/plant (g)	
0	3.8	7.0	73.6	179.8	13.7	33.6
15	4.7	8.0	102.5	210.6	19.1	38.8
30	5.7	9.3	126.1	250.8	23.5	46.7
45	7.3	8.6	159.2	223.1	29.6	41.3
Comparisons						
1. Two sprouting durations at the same cultivar:						
a. S.Em±	0.17		3.70		0.67	
	0.49		10.21		1.91	
2. Two cultivars at the same or different duration(s) of sprouting:						
a. S.Em±	0.23		3.90		0.71	
b. CD at 5%	0.71		12.07		2.19	

Table 19. Interaction effect between dates of planting and cultivars on fresh and dry weight of tubers/plant (g)

Date of planting	Cultivar			
	V_1	V_2	V_1	V_2
	a. Tubers fresh weight/plant(g)		b. Tubers dry weight/plant(g)	
P_1	131.61	214.72	24.70	39.61
P_2	97.08	217.39	18.24	40.60
S.Em±	3.15		0.57	
CD at 5%	10.90		1.98	

well as dry weight of tubers per plant as compared to QB/A-9-120.

The per plant fresh and dry weight of tubers were also influenced significantly by interaction between duration of sprouting and cultivars (Table 18) and also between date of planting and cultivars (Table 19). The tuber fresh weight in QB/A-9-120 (V_1) increased significantly and consistently with increase in duration of sprouting from S_1 to S_4. Similar trend was recorded in Kufri Jyoti except that the increase was significant only upto 30 days sprouting duration. Comparison of the two cultivars for any given duration of sprouting indicated that Kufri Jyoti produced significantly higher tuber fresh weight than QB/A-9-120 at all durations of sprouting. Exactly similar trend in respect of the interaction between duration of sprouting and cultivars on tuber dry matter content was noticed.

A perusal of Table 19 indicated that delay in planting did not decrease per plant fresh as well as dry weight of Kufri Jyoti but in QB/A-9-120, P_2 planting reduced both these parameters significantly compared to P_1 planting. Further comparisons revealed that irrespective of date of planting, Kufri Jyoti recorded significantly higher fresh and dry weights per plant than QB/A-9-120.

4.5 TUBER YIELD

4.5.1 Grade wise tuber yield

The tuber yield as influenced by various treatments was recorded in four different grades viz., A (>75 g), B (50-75 g), C (25-50 g) and D (<25 g) and the relevant data have been presented in Table 20 and depicted in figure 7. Their analyses of variance have been given in Appendix VI.

The influence of duration of sprouting on the gradewise yield of potato was significant. The yield in the grades A, B, and C was significantly higher in 45 days sprouting duration treatment as compared to all other sprouting durations except that the yield in grade 'C' in S_4 and S_3 sprouting durations was statistically similar (Table 20). The yield decreased significantly and consistently with decrease in the duration of sprouting and lowest yield was recorded in S_1. In respect of yield in grade 'D', 30 days sprouting duration significantly out performed (15.27 q ha^{-1}) the 45 days sprouting duration (13.08 q ha^{-1}). Remaining two treatments (S_1 and S_2), however, remained at par with each other.

The effect of date of planting was not significant in respect of yield of 'A' as well as 'C' grade tubers. However, the yield of grade 'B' and 'D' tubers was significantly higher in first date of planting as compared to second date of planting. Between cultivars Kufri Jyoti produced significantly more yield than QB/A-9-120 in all the grades of potato. The increase in yield of Kufri Jyoti over QB/A-9-120 in grades 'A', 'B', 'C' and 'D' was 124.1, 140.5, 189.2 and 125.1 per cent, respectively.

Table 20. Effect of duration of sprouting, date of planting and cultivars on yield of potato

Treatment	Grade wise tuber yield (q/ha)				Total tuber yield(q/ha)	Dry matter yield(q/ha
	A	B	C	D		
Duration of sprouting (days)						
0	17.36 (26.9)*	20.00 (31.0)	17.71 (27.4)	9.49 (14.7)	64.58	12.87
15	23.59 (28.8)	25.35 (31.0	25.57 (27.6)	10.30 (12.6)	81.83	16.55
30	31.42 (27.9)	37.04 (32.9)	29.87 (25.6)	15.27 (13.6)	112.62	23.14
45	35.01 (29.2)	43.64 (36.4	28.17 (23.5)	13.08 (10.9)	119.91	24.46
S.Em±	0.81	1.05	0.73	0.71	1.55	0.31
CD at 5%	2.36	3.08	2.13	2.09	4.53	0.90
CV (%)	11.74	11.62	10.21	20.65	5.68	7.90
Date of planting						
January 25	27.15 (26.2)	37.84 (36.5)	25.39 (24.5)	13.19 (12.7)	103.59	21.31
February 9	26.55 (30.9)	25.17 (29.3)	23.26 (27.1)	10.88 (12.7)	85.88	17.21
S.Em±	0.57	0.58	0.93	0.48	1.20	0.26
CD at 5%	NS	2.01	NS	1.69	4.17	0.89
CV (%)	10.58	9.05	18.46	19.91	6.24	9.28
Cultivar						
QB/A-9-120	16.50 (30.0)	18.50 (33.7)	12.50 (22.8)	7.40 (13.5)	54.92	10.71
Kufri jyoti	37.19 (27.6)	44.50 (33.1)	36.15 (26.9)	16.66 (12.4)	134.54	27.80
S.Em±	0.57	0.58	0.93	0.48	1.20	0.26
CD at 5%	2.00	2.01	3.21	1.69	4.17	0.89
CV (%)	10.58	9.05	18.46	19.91	6.24	9.28

NS - Not significant
* Figures within parentheses represent percentage of total tuber yield

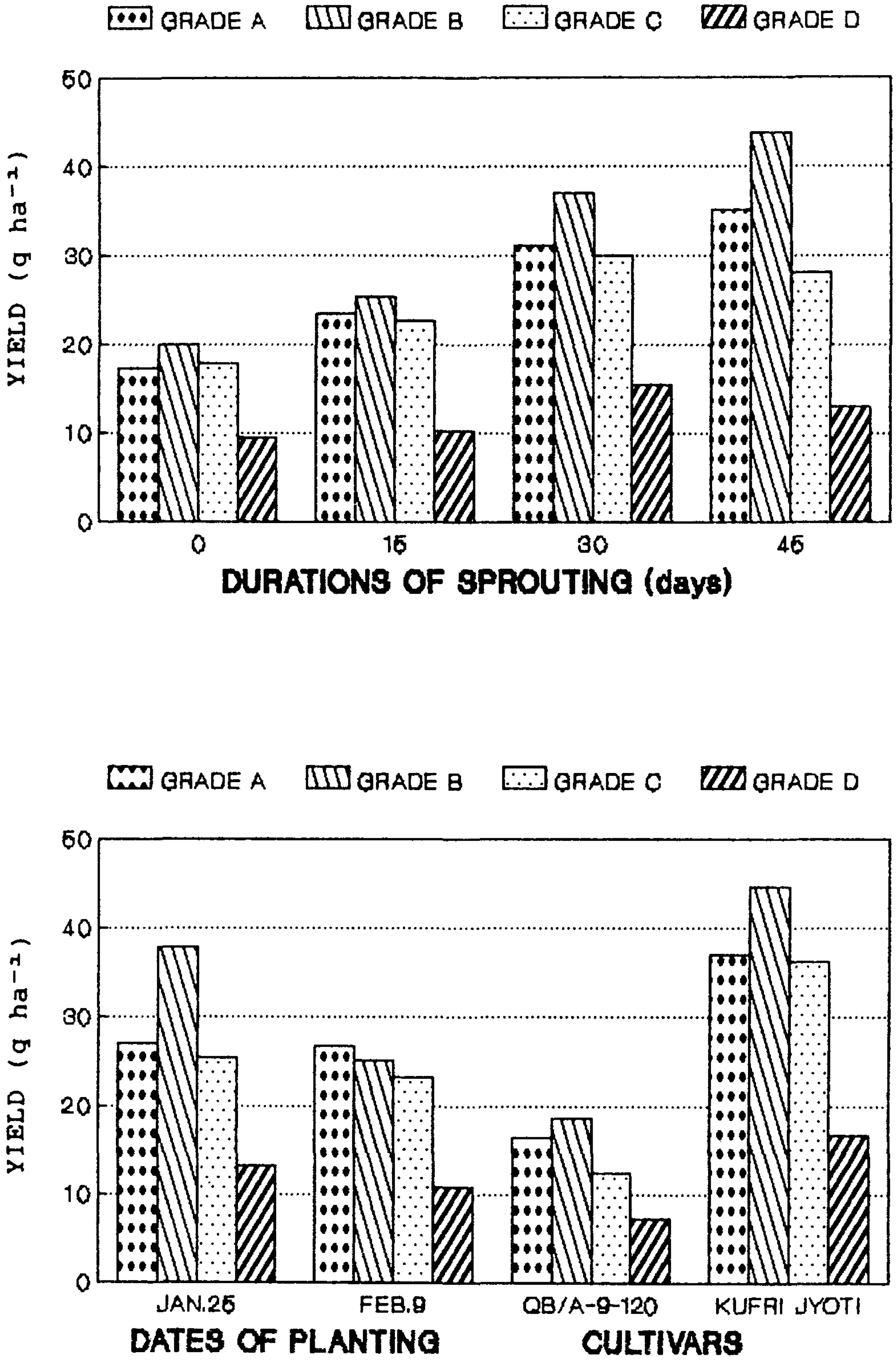


FIG.7 EFFECT OF SPROUTING DURATIONS, PLANTING DATES AND CULTIVARS ON GRADE WISE TUBER YIELD (q ha^{-1})

The yield of potato in various grades ('A', 'B', 'C' and 'D') was influenced significantly by the interaction between duration of sprouting and cultivars (SxV). Produce in grade 'D' was also affected significantly by interaction between sprouting duration and date of planting (SxP). Further, a higher order interaction involving duration of sprouting, date of planting and cultivars (SxPxV) also influenced the yield in 'B' and 'C' grades and the relevant data have been presented in Table 22 and depicted in figures 9 and 10 , respectively. In view of the presence of higher order interactions, the lower order interaction effects have been presented only in respect of grades 'A' and 'D' (Table 21). The data in respect of grade 'A' have also been shown graphically in Figure 8.

The data presented in Table 21 revealed that the yield of cultivar QB/A-9-120 in grade 'A' was significantly higher when it was planted after sprouting for 45 days (S_4). This treatment was followed by S_3 which yielded significantly higher than S_1. Fifteen days sprouting duration, however remained at par with S_1 as well as S_3. In Kufri Jyoti significantly higher tuber yield ('A' grade) was recorded in 30 days sprouting period. This treatment was followed by S_4, S_2 and S_1, respectively. At any given duration of sprouting, cultivar QB/A-9-120 resulted in significantly lower yield than Kufri Jyoti.

In respect of produce of grade 'D' tubers, durations of sprouting differed significantly among themselves only in

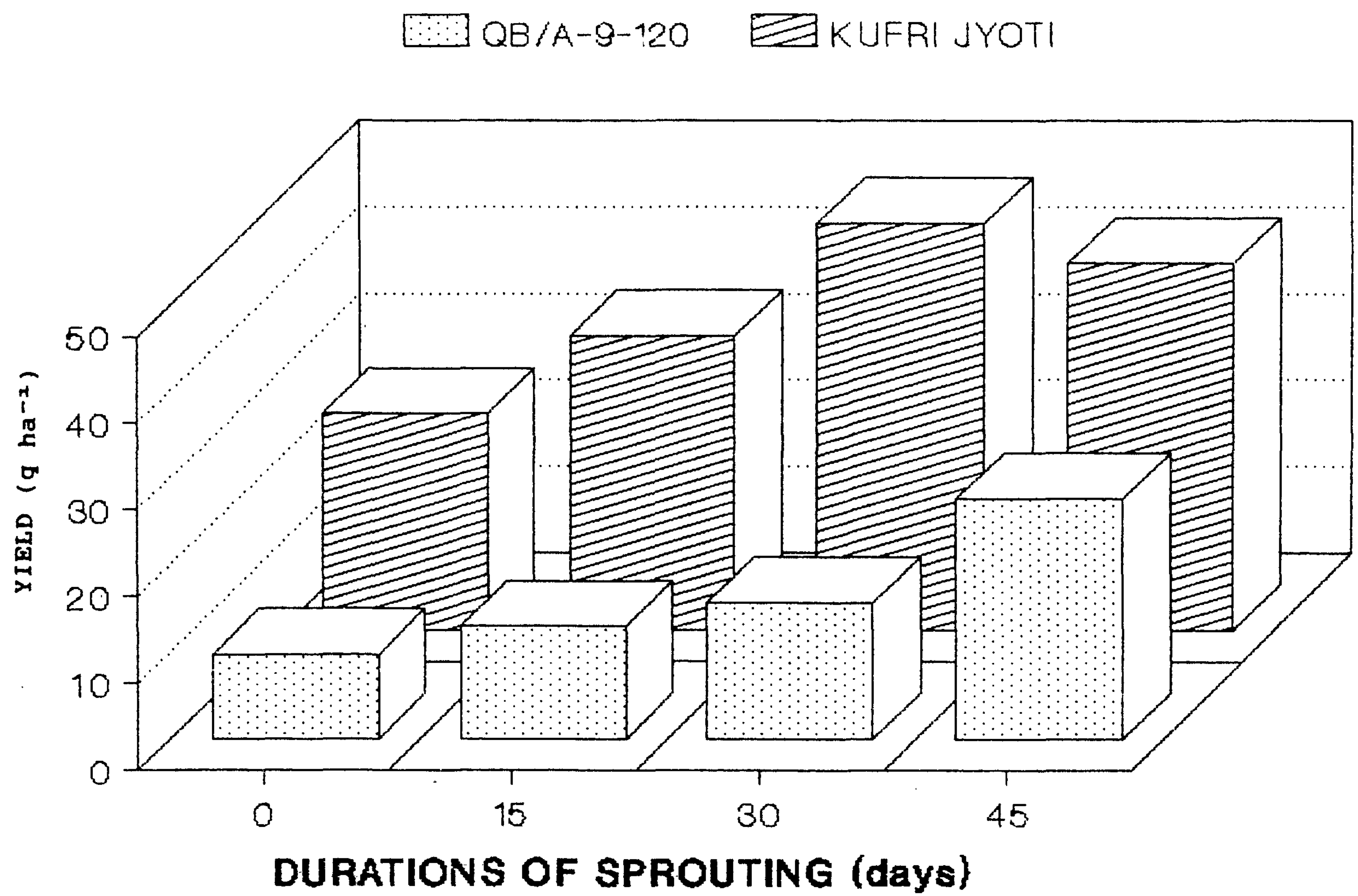


FIG.8 INTERACTION EFFECT OF SPROUTING DURATIONS AND CULTIVARS ON GRADE 'A' TUBER YIELD (q ha^{-1})

Table 21. Interaction effect between durations of sprouting and cultivars and between durations of sprouting and date of planting on gradewise tuber yield (q/ha)

Duration of sprouting (days)	Cultivar				Date of planing	
	V_1	V_2	V_1	V_2	P_1	P_2
	Grade 'A'		Grade 'D'		Grade 'D'	
0	9.72	25.00	6.25	12.73	11.80	7.17
15	12.96	34.02	6.25	14.35	12.50	8.10
30	15.74	46.99	8.56	21.99	14.58	15.97
45	27.78	42.36	8.56	17.59	13.89	12.27

Comparisons

1. Two sprouting durations at the same cultivar/planting:

a.	S.Em±	1.29	1.09	1.09
b.	CD at 5%	3.75	2.96	2.96

2. Two cultivars/plantings at the same or different duration(s) of sprouting;

a.	S.Em±	1.77	1.15	1.15
b.	CD at 5%	5.36	3.39	3.39

Table 22. Interaction effect between durations of sprouting, dates of planting and cultivars on gradewise tuber yield (q/ha)

Duration of sprouting (days)	QB/A-9-120		Kufri Jyoti	
	P_1	P_2	P_1	P_2
	A. Grade 'B'			
0	11.98	8.33	31.02	28.7
15	15.28	8.33	43.52	34.26
30	22.23	12.50	66.67	46.76
45	49.08	20.37	62.98	42.13

Comparisons

1. Two sprouting durations at the PxV combination:
   a. S.Em± 2.11
   b. CD at 5% 6.02

2. Two PxV combinations at the same or different duration(s) of sprouting
   a. S.Em± 2.82
   b. CD at 5% 8.48

Duration of sprouting (days)	QB/A-9-120		Kufri Jyoti	
	P_1	P_2	P_1	P_2
	B. Grade 'C'			
0	8.33	6.95	30.56	25.00
15	9.26	7.21	43.39	30.56
30	12.03	11.57	52.32	43.51
45	25.16	18.98	30.09	42.13

Comparisons

1. Two sprouting durations at the same PxV combination:
   a. S.Em± 1.46
   b. CD at 5% 4.27
2. Two PxV combinations at the same or different duration(s) of sprouting
   a. S.Em± 1.83
   b. CD at 5% 5.85

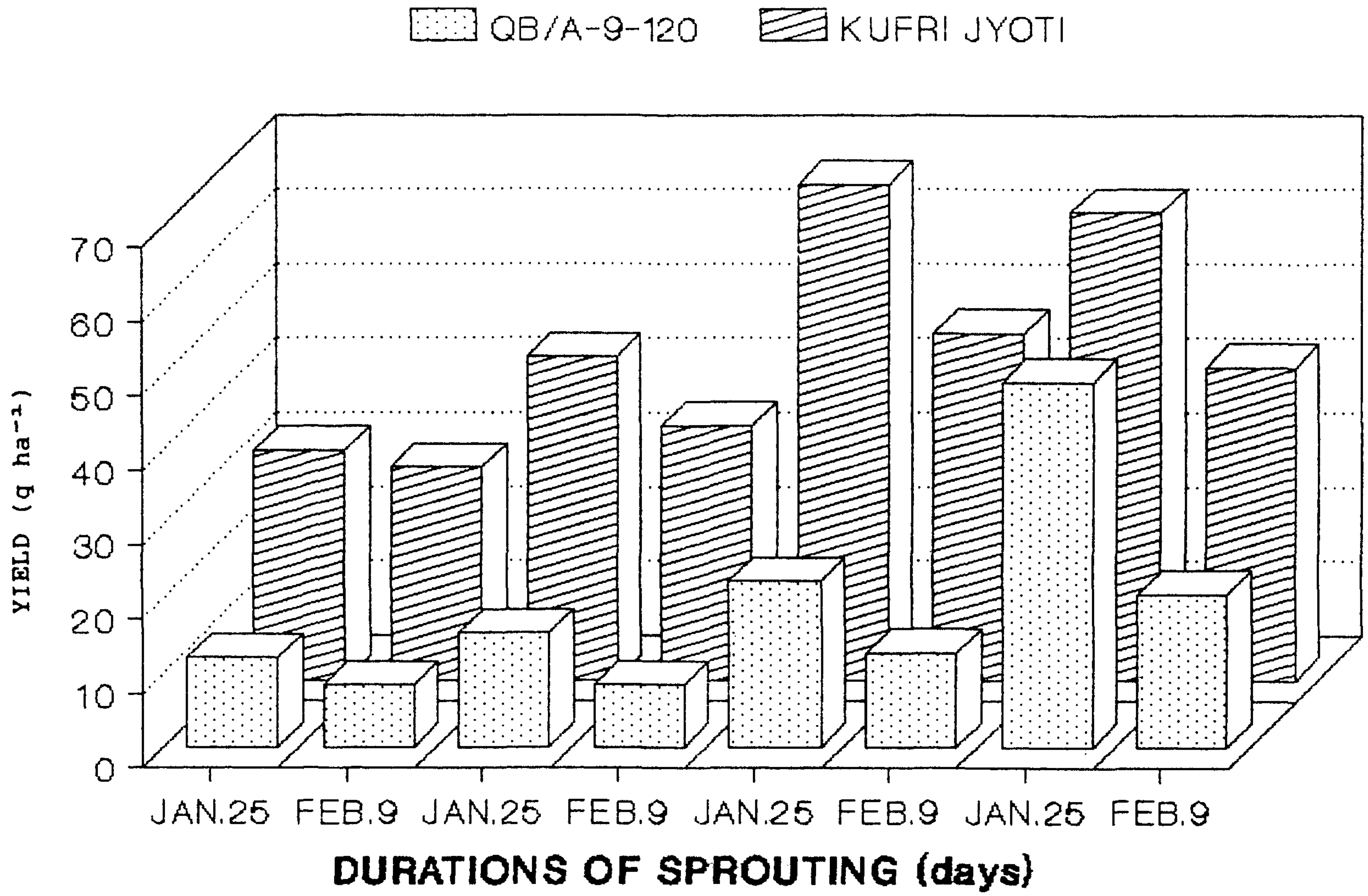


FIG.9 INTERACTION EFFECT OF SPROUTING DURATIONS, PLANTING DATES AND CULTIVARS ON GRADE 'B' TUBER YIELD (q ha^{-1})

Kufri jyoti where highest and lowest yields were recorded by S_3 and S_1 and S_2 treatments, respectively. Intermediate behaviour was exhibited by S_4 sprouting duration. Further the yield of QB/A-9-120 recorded under different durations of sprouting was significantly lower than the corresponding yield of Kufri Jyoti. As regards the interaction between PxS (Table 21), significant differences among different durations of sprouting were present only in delayed planting (9th February) where highest and lowest tuber yields ('D' grade) were recorded in S_3 and S_2 and S_1 treatments, respectively. Planting dates differed significantly between themselves only in S_1 and S_2 sprouting durations when P_1 proved better than P_2.

The data on the effect of interaction between duration of sprouting, date of planting and cultivars on yield of grade 'B' tubers revealed that at all levels of sprouting durations the yield of Kufri Jyoti planted on first date was significantly higher than its yield corresponding to second date of planting except at S_1 sprouting duration, when the yield recorded on both dates was statistically similar (Table 22). On the other hand, the yield of QB/A-9-120 planted on first date was significantly higher than its yield on second date only at S_3 and S_4 sprouting durations. It was interesting to note that the yield of QB/A-9-120 (V_1) recorded on either date was significantly lower than the yield of Kufri Jyoti corresponding to any date of planting except that P_1V_1 remained statistically similar to P_2V_2.

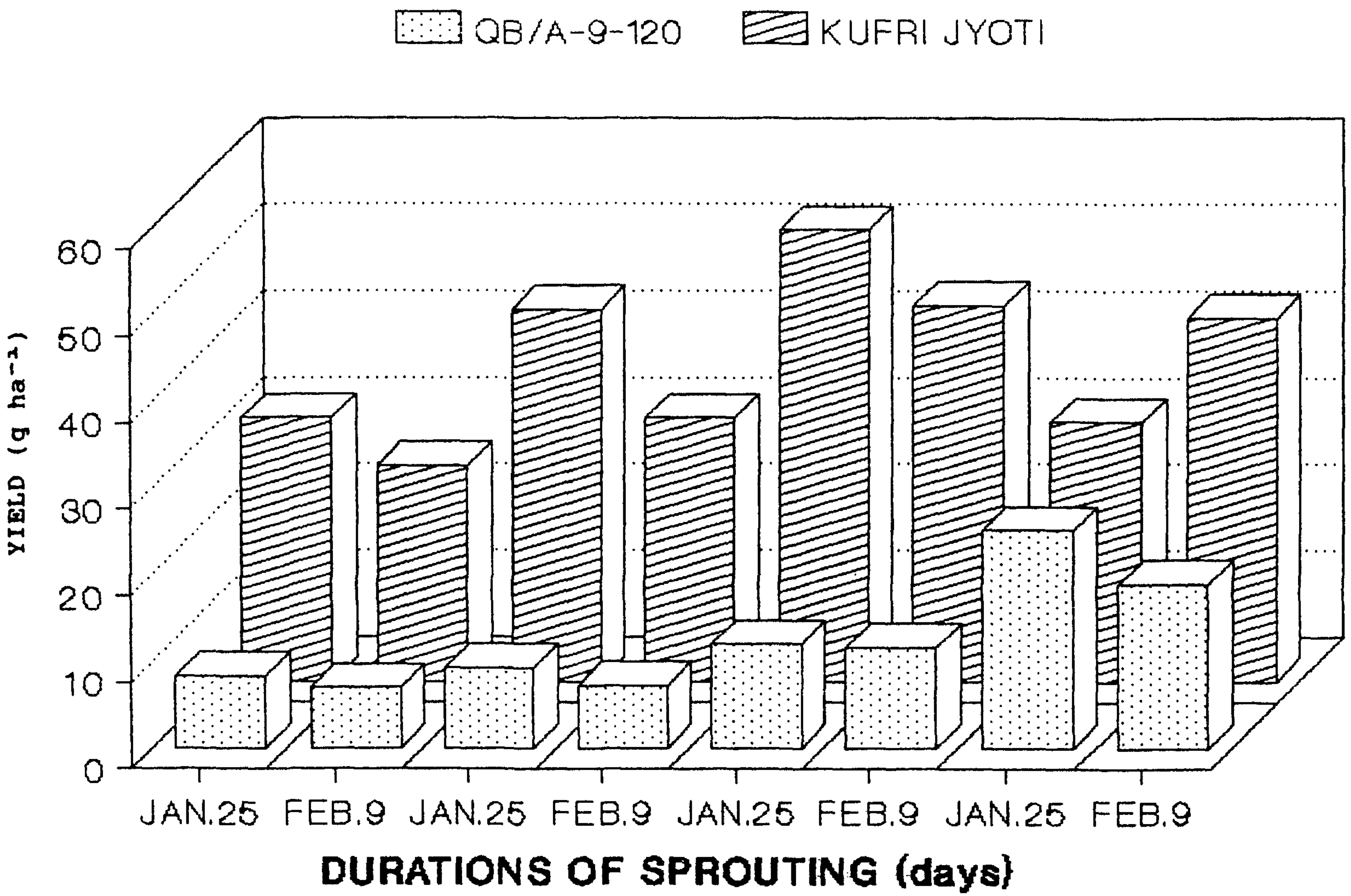


FIG.10 INTERACTION EFFECT OF SPROUTING DURATIONS, PLANTING DATES AND CULTIVARS ON GRADE 'C' TUBER YIELD (q ha^{-1})

When the performance of QB/A-9-120 corresponding to different durations of sprouting was compared at different dates of planting (Table 22), it was found that 45 days sprouting duration resulted in higher 'B' grade produce than 30 days duration which in turn, proved significantly superior to 15 days sprouting duration except for second date of planting. Treatment S_2 and S_1 behaved statistically alike. As regards the response of Kufri Jyoti (V_2) both S_3 and S_4 remaining at par produced more 'B' grade tubers than S_2 and S_1. The latter two treatments (S_2 and S_1) differed significantly at first date of planting.

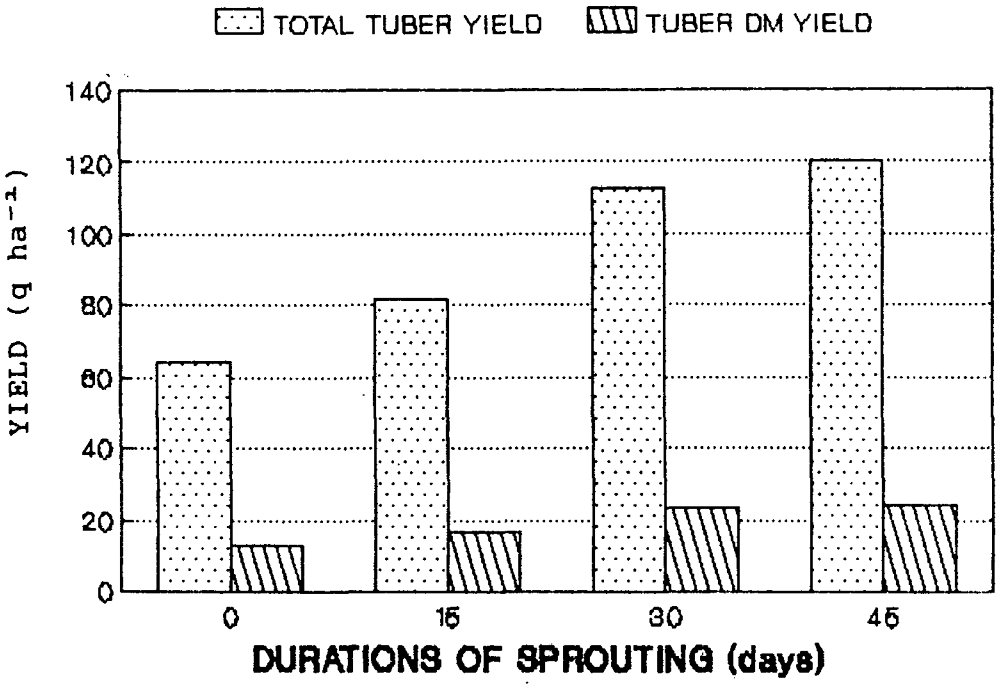
The effect of different durations of sprouting on the production of 'C' grade tubers in QB/A-9-120 (Table 22) was quite peculiar and the ranking of different sprouting durations was in the order $S_3 > S_2 > S_4 = S_1$. When the planting of this cultivar was delayed to 9th February (P_2), 30 days sprouting duration (S_3) remaining at par with 45 days duration (S_4) resulted in significantly higher grade 'C' produce than S_2 which in turn, proved better than S_1. In Kufri Jyoti significantly higher yield ('C' grade) was recorded in 45 days sprouting duration compared to S_3 sprouting duration irrespective of date of planting. The latter treatment (S_3) however, yielded higher than 15 days sprouting duration only in 9th February planting. Fifteen days sprouting duration remained at par with control (no sprouting) in this variety (Kufri Jyoti).

Comparison of combinations of cultivar and date of planting at different durations of sprouting revealed that the production of 'C' grade tubers was significantly highest when Kufri Jyoti was planted on 25th January (P_1V_2) in S_1, S_2 or S_3 sprouting durations. This combination was followed by planting of Kufri Jyoti on 9th February (P_2V_2) which, in turn, was again significantly better than that of QB/A-9-120 planted on 25th January. The yield of grade 'C' tubers of QB/A-9-120 in sprouting durations viz., S_1, S_2 and S_3 did not decrease significantly when the planting was delayed from 25th January to 9th February. In S_4 sprouting duration signficantly higher yield was obtained in combintion P_2V_2 followed by P_1V_2 as well as P_1V_1. Significantly lowest yield ('C' grade) was recorded in QB/A-9-120 in delayed planting (P_2V_1).

4.5.2 Total tuber yield and dry matter yield

The data on total tuber yield and dry matter yield as influenced by different treatments have been presented in Table 20 and also shown graphically in figure 11. The corresponding analyses of variance have been appended in Appendix VI.

Total tuber yield as well as tuber dry matter yield increased significantly and consistently with increase in duration of sprouting from 0-45 days (Table 20). Thus, maximum tuber yield (119.91 q ha^{-1}) was recorded in 45 days sprouting duration and minimum (64.58 q ha^{-1}) in control.



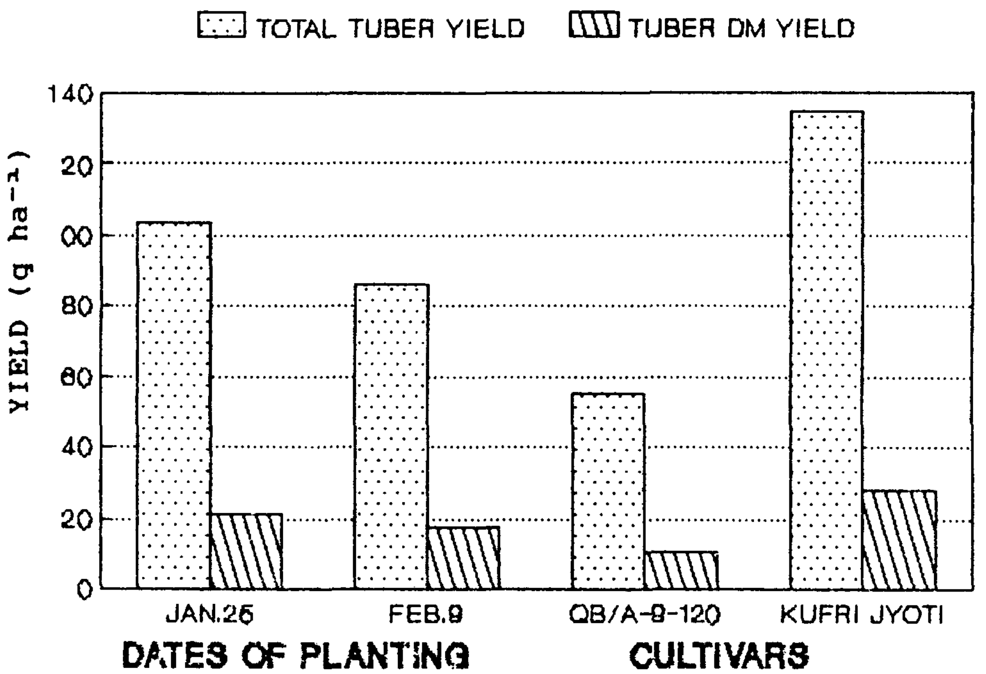


FIG.11 EFFECT OF SPROUTING DURATIONS, PLANTING DATES AND CULTIVARS ON TOTAL TUBER YIELD AND DRY MATTER YIELD (q ha^{-1})

Between plantings, 25th January resulted in 20.6 and 23.8 per cent higher total tuber yield and dry matter yield, respectively over 9th February planting. Corresponding yield increases in Kufri Jyoti compared to QB/A-9-120 were 145.0 and 159.6 per cent, respectively.

Tuber yield and tuber dry matter yields were also influenced by interaction among various experimental factors viz., duration of sprouting, dates of planting and cultivars (Table 23). Irrespective of the date of planting, the tuber yield decreased significantly and consistently in QB/A-9-120 with decrease in duration of sprouting from 45 to 15 days. Further decrease in sprouting duration did not decrease the yield (Fig. 12). Similar trend was observed in respect of tuber dry matter yield of QB/A-9-120 except that this decrease in delayed planting (9th February) continued upto control treatment (S_1). In Kufri Jyoti, both tuber yield and tuber dry matter yield was in the order $S_1 < S_2 < S_4 < S_3$ irrespective of the date of planting.

On comparison of total tuber yield of a main plot at different durations of sprouting it was observed that early planting of Kufri Jyoti (25th January) resulted in significantly higher yield than that from late planting which in turn, was also better than QB/A-9-120 planted on either date in S_1, S_2 as well as S_3 sprouting duration treatments. When crop was raised using tubers sprouted for 45 days (S_4), variety Kufri Jyoti planted on first date remained at par

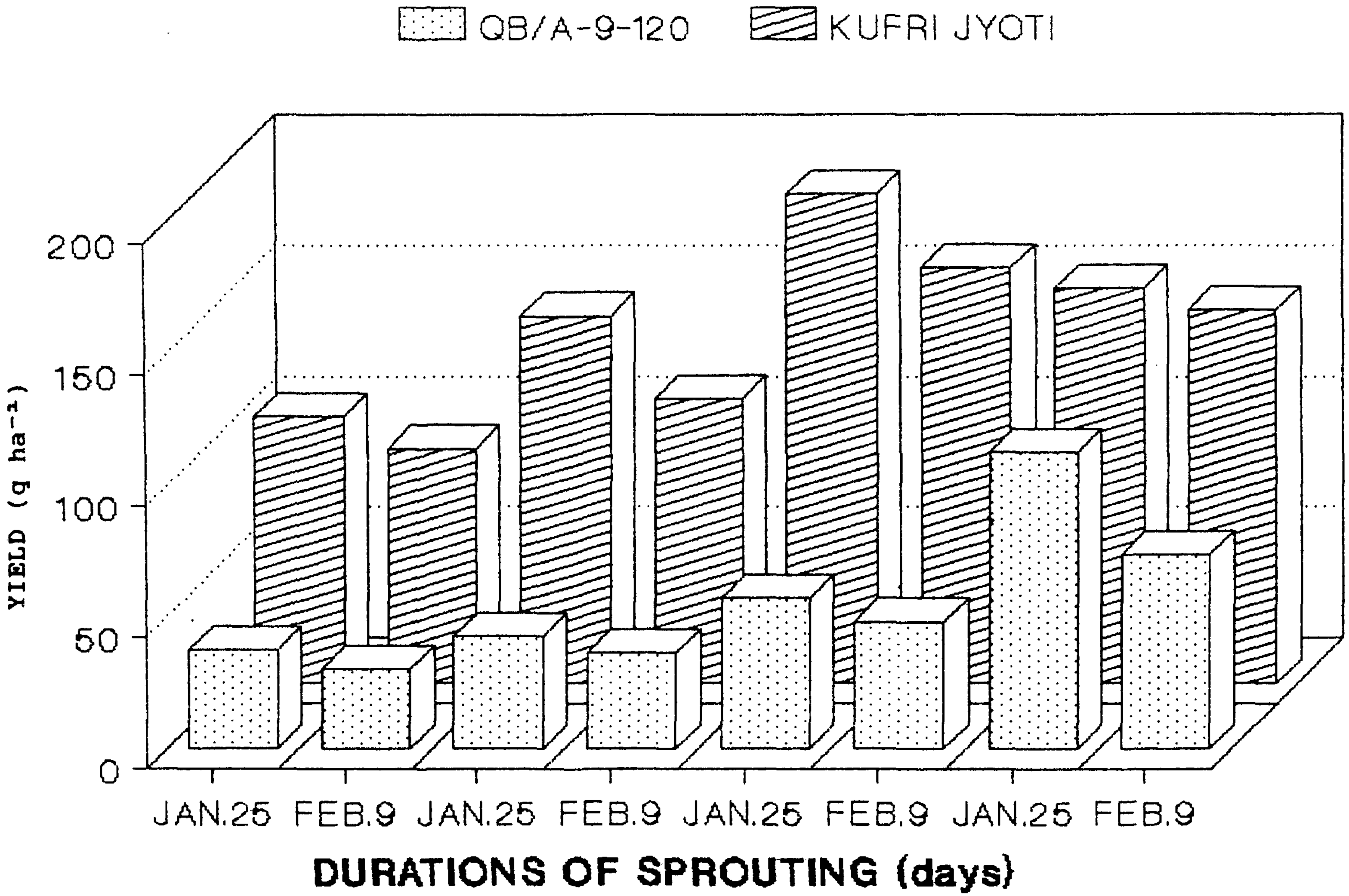


FIG.12 INTERACTION EFFECT OF SPROUTING DURATIONS, PLANTING DATES AND CULTIVARS ON TOTAL TUBER YIELD ($q\ ha^{-1}$)

Table 23. Interaction effect between durations of sprouting, dates of planting and cultivars on total yield (q/ha)

Duration of sprouting (days)	QB/A-9-120		Kufri Jyoti	
	P_1	P_2	P_1	P_2
	A. Total tuber yield			
0	37.50	30.09	101.39	89.36
15	42.59	36.57	139.82	108.34
30	57.41	48.15	186.58	158.34
45	112.97	74.07	150.47	142.14

Comparisons

1. Two sprouting durations at the same PxV combination:
   a. S.Em± 3.10
   b. CD at 5% 9.06
2. Two PxV combinations at the same or different duration(s) of sprouting:
   a. S.Em± 3.18
   b. CD at 5% 9.97

	B. Tubers dry matter yield			
0	7.28	5.56	20.73	17.91
15	8.35	6.82	28.99	22.05
30	11.37	9.06	39.25	32.91
45	23.14	14.14	31.38	29.20

Comparisons

1. Two sprouting durations at the same PxV combination:
   a. S.Em± 0.62
   b. CD at 5% 1.80
2. Two PxV combinations at the same or different duration(s) of sprouting:
   a. S.Em± 0.65
   b. CD at 5% 2.00

with its planting on second date and both in turn, yielded higher than QB/A-9-120 planted on either date. However, in the latter cultivar, P_1 planting was superior to P_2 planting. In respect of tuber dry matter yield under different durations of sprouting, the order of dry matter production of various main plot factors (planting dates and cultivars) was P_1V_2 > P_2V_2 > P_1V_1 > P_2V_1 except that the latter two treatments were statistically similar in S_2 sprouting duration..

4.6 QUALITY PARAMETERS

The data pertaining to the effect of various treatments on quality parameters of potato viz., tuber dry matter content, starch content, protein content and specific gravity have been presented in table 24 and their analyses of variance appended in Appendix VII.

4.6.1 Tuber dry matter content

The effect of duration of sprouting on tuber dry matter content was significant and the content increased significantly and consistently with increase in duration of sprouting from 0 to 45 days. Between planting dates, the dry matter content was significantly higher in P_1 planting (25th January) than P_2 planting (9th February). Whereas, between cultivars Kufri Jyoti resulted in higher dry matter content than QB/A-9-120.

The effect of interaction between duration of sprouting and cultivars on dry matter content was also significant (Table 25). Tuber dry matter content in

Table 24. Effect of duration of sprouting, date of planting and cultivar on tuber quality

Treatment	Dry matter content (%)	Starch content (%)	Protein content (%)	Specific gravity
Duration of sprouting (days)				
0	19.61	71.32	10.68	1.06
15	19.84	73.17	11.77	1.07
30	20.11	75.83	12.72	1.09
45	20.24	75.46	12.29	1.08
S.Em±	0.03	0.17	0.21	0.01
CD at 5%	0.08	0.50	0.61	0.02
CV (%)	0.05	0.81	6.12	1.12
Date of planting				
January 25	20.30	73.37	11.95	1.08
February 9	19.60	74.52	11.78	1.08
S.Em±	0.04	0.34	0.23	0.01
CD at 5%	0.14	NS	NS	NS
CV (%)	1.03	2.25	9.80	1.26
Cultivar				
QB/A-9-120	19.30	73.81	12.39	1.07
Kufri Jyoti	20.60	74.07	11.34	1.08
S.Em±	0.04	0.34	0.23	0.01
CD at 5%	0.14	NS	0.82	NS
CV (%)	1.03	2.25	9.80	1.26

NS - Not significant

QB/A-9-120 (V_1) was significantly lower compared to Kufri Jyoti (V_2) at all the durations of sprouting. As regards the effect of sprouting duration on cultivars, 30 days sprouting duration (S_3) recorded significantly higher dry matter content in Kufri Jyoti than S_4, S_2 and S_1 treatments. The latter three treatments also differed significantly among themselves. However in QB/A-9-120 highest dry matter was recorded in S_4 followed by S_3, S_2 and S_1 treatments, respectively.

4.6.2 Starch content

The starch content was influenced significantly by the duration of sprouting treatment, the effect of planting dates as well as cultivars on this parameter was not significant. Thirty days sprouting duration remaining at par with 45 days duration resulted in significantly higher starch content than 15 days sprouting duration and no sprouting. Significantly minimum starch content was recorded in control treatment (S_1).

The starch content was also influenced significantly by the interaction between duration of sprouting and cultivars (Table 25). Significantly highest and lowest content were recorded in S_3 and S_1 in variety Kufri Jyoti and S_4 and S_1 in QB/A-9-120, respectively. The contents of starch were statistically similar in both the cultivars in S_1, S_2 and S_3 sprouting durations but in S_4 the starch content in Kufri Jyoti was significantly higher compared with QB/A-9-120,

4.6.3 Protein content

The protein contents in the produce from S_3 and S_4 treatments were similar but significantly higher compared to S_1 treatment. Treatment S_4, however, also remained at par with S_2. In respect of planting dates, planting on first date (25th January) resulted in significantly higher protein content than late planting (9th February). Between cultivars, protein content in QB/A-9-120 was significantly higher than Kufri Jyoti.

The data on the effect of interaction between duration of sprouting and cultivars on protein content have been presented in Table 25. The perusal of data revealed a significant and consistent increase in protein content of Kufri Jyoti with increase in duration of sprouting upto 30 days. However, further increase in sprouting duration to S_4 (45 days) did not decrease the protein content and it was at par with S_1. Similarly, in QB/A-9-120 significantly lowest and highest protein contents were recorded in S_1 and S_4 treatments, respectively. S_2 and S_3 however, did not differ significantly between themselves in this cultivar. Comparison of cultivars revealed that both cultivars had similar protein content at S_1, S_2 and S_3 sprouting durations but at S_4 the protein content in QB/A-9-120 was significantly higher than Kufri Jyoti.

4.6.4 Specific gravity

Tuber specific gravity was influenced significantly by durations of sprouting (Table 24). Thirty days sprouting

Table 25. Interaction effect between durations of sprouting and cultivars on tuber quality

Duration of sprouting (days)	Cultivar					
	V_1	V_2	V_1	V_2	V_1	V_2
	Dry matter content (%)		Starch content (%)		Protein content (%)	
0	18.98	20.30	71.00	71.64	11.19	10.17
15	19.13	20.60	72.96	73.37	12.19	11.34
30	19.32	20.91	75.13	76.53	12.51	12.94
45	19.79	20.79	76.16	74.76	13.63	10.90

Comparisons

1. Two sprouting durations at the same cultivar:

	Dry matter	Starch	Protein
a. S.Em±	0.04	0.24	0.29
b. CD at 5%	0.12	0.71	0.86

2. Two cultivars at the same or different duration(s) of sprouting:

	Dry matter	Starch	Protein
a. S.Em±	0.06	0.39	0.35
b. CD at 5%	0.18	1.32	1.09

duration while remining at par with 45 and 15 days sprouting durations resulted in significantly higher tuber specific gravity than control treatment. The latter (S_1) however, also remained at par with S_4 and S_2 treatments. The effect of date of planting as well as cultivars on specific gravity was not significant.

4.7 STORAGE STUDIES

The data pertaining to periodic observations (10 days interval) on cumulative moisture loss, rottage and sprouting percentage of tubers kept under ordinary storage as influenced by various experimental factors viz., durations of sprouting, dates of planting and cultivars have been presented in Tables 26, 28 and 29 . The analyses of variance of these data have been presented in Appendix VIII. The data on moisture loss and rottage as recorded on 30th, 60th and 90th day of storage, have also been presented in Figures 13 and 14 respectively. However, it may be mentioned that no tuber rottage and tuber sprouting was observed in the first 20 days of storage. Hence, first observation in respect of these two parameters was recorded on 30th day of storage.

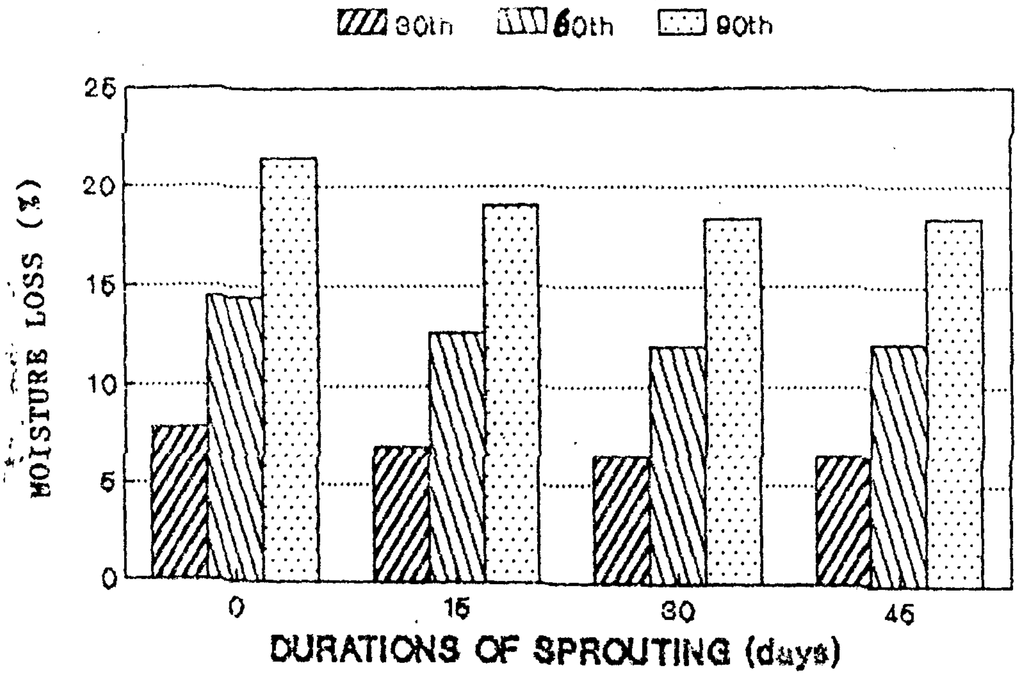
4.7.1 Cumulative moisture loss

The cumulative moisture loss under storage was influenced by all the experimental factors viz., durations of sprouting, dates of planting and cultivars at all the intervals of time (Table 26). Significantly highest cumulative moisture loss was observed in no

Table 26. Effect of duration of sprouting, date of planting and cultivar on moisture loss during storage

Treatment	Day of storage period								
	10th	20th	30th	40th	50th	60th	70th	80th	90th
Duration of sprouting (days)									
0	1.75 (3.09)*	2.30 (5.35)	2.79 (7.35)	3.23 (10.43)	3.55 (12.60)	3.81 (14.51)	4.05 (16.40)	4.37 (19.09)	4.64 (21.52)
15	1.66 (2.79)	2.14 (4.64)	2.61 (6.86)	3.00 (9.00)	3.33 (11.08)	3.57 (12.74)	3.80 (14.44)	4.10 (16.81)	4.37 (19.09)
30	1.59 (2.55)	2.06 (4.28)	2.52 (6.41)	2.91 (8.46)	3.23 (10.43)	3.47 (12.04)	3.70 (13.69)	4.02 (16.16)	4.28 (18.31)
45	1.58 (2.53)	2.06 (4.28)	2.52 (6.41)	2.93 (8.58)	3.24 (10.49)	3.48 (12.11)	3.72 (13.83)	4.03 (16.24)	4.29 (18.40)
S.Em±	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02
CD at 5%	0.08	0.08	0.08	0.08	0.08	0.06	0.07	0.07	0.07
CV (%)	5.79	4.17	3.62	3.15	2.69	2.29	2.41	2.07	1.86
Date of planting									
January 25	1.59 (2.57)	2.06 (4.30)	2.50 (6.32)	2.91 (8.46)	3.23 (10.43)	3.46 (11.97)	3.70 (13.69)	4.02 (16.16)	4.29 (18.40)
February 9	1.70 (2.91)	2.22 (4.98)	2.72 (7.43)	3.12 (9.73)	3.45 (11.90)	3.70 (13.69)	3.93 (15.44)	4.24 (17.97)	4.50 (20.25)
S.Em±	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02
CD at 5%	0.06	0.06	0.04	0.04	0.04	0.03	0.03	0.03	0.05
CV (%)	4.97	3.80	3.46	1.69	1.64	1.30	1.20	1.49	1.68
Cultivar									
QB/A-9-120	1.70 (2.91)	2.22 (4.97)	2.73 (7.50)	3.16 (9.98)	3.49 (12.18)	3.74 (13.98)	3.98 (15.84)	4.28 (18.31)	4.54 (20.61)
Kufri Jyoti	1.60 (2.58)	2.06 (4.31)	2.49 (6.25)	2.87 (8.23)	3.19 (10.17)	3.42 (11.69)	3.65 (13.32)	3.98 (15.84)	4.25 (18.06)
S.Em±	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02
CD at 5%	0.06	0.06	0.04	0.04	0.04	0.03	0.03	0.03	0.05
CV (%)	4.97	3.80	3.46	1.69	1.64	1.30	1.20	1.49	1.68

*Figures within parentheses indicate original values



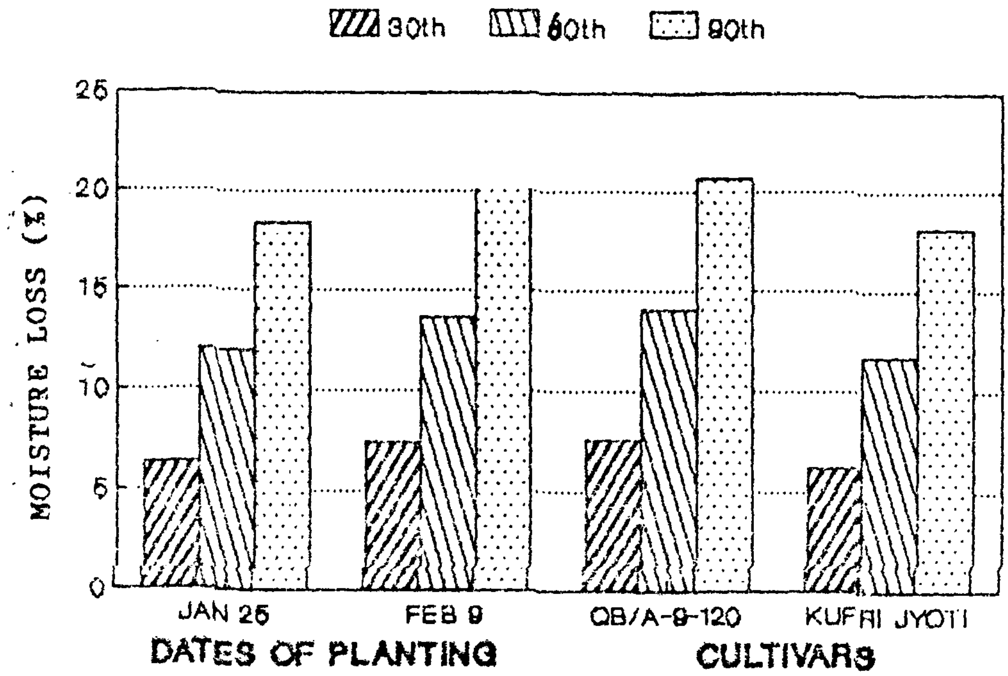


FIG.13 EFFECT OF SPROUTING DURATIONS, PLANTING DATES AND CULTIVARS ON MOISTURE LOSS (%) ON 30th, 60th AND 90th DAY OF STORAGE

sprouting treatment (S_1) followed by S_2 sprouting duration. The S_3 and S_4 treatments while remaining at par recorded significantly lowest moisture loss except that these treatments also remained at par with S_2 on 10th day of storage. Further, the cumulative moisture loss under S_4 treatment was also similar to that recorded under S_2 on 40th and 80th day of storage.

In respect of planting dates, first date of planting (25th January) recorded significantly lower cumulative moisture loss than P_2 (9th February) at all the dates of observation. The moisture loss recorded for Kufri Jyoti was significantly lower than QB/A-9-120.

Cumulative moisture loss was influenced significantly by the interaction between duration of sprouting and cultivars at all the dates of observation except the first two observations i.e., on 10th and 20th day of storage (Table 27). In Kufri Jyoti, cumulative moisture loss decreased significantly and consistently with increase in duration of sprouting from S_1 to S_3 at all the dates of observation. Further, increase in duration of sprouting to 45 days (S_4) did not decrease the moisture loss, instead the moisture loss in this treatment remained at par with S_2 treatment. In cultivar QB/A-9-120 also, cumulative moisture loss decreased with increase in duration of sprouting and significantly lowest moisture loss was recorded in S_4 treatment. However, S_2 and S_3 behaved statistically alike in this cultivar. Comparison of cultivars revealed that QB/A-9-120 recorded

Table 27. Interaction effect between durations of sprouting and cultivars on moisture loss (%) during storage

Duration of sprouting (days)	Cultivar V1 30th	V2 30th	V1 40th	V2 40th	V1 50th	V2 50th	V1 60th	V2 60th
0	2.93 (8.64)*	2.66 (7.07)	3.36 (11.35)	3.09 (9.56)	3.69 (13.68)	3.42 (11.72)	3.96 (15.70)	3.66 (13.44)
15	2.73 (7.46)	2.50 (6.27)	3.16 (9.99)	2.86 (8.20)	3.49 (12.22)	3.17 (10.06)	3.74 (13.99)	3.40 (11.62)
30	2.69 (7.26)	2.35 (5.56)	3.13 (9.82)	2.70 (7.34)	3.47 (12.08)	3.00 (9.01)	3.73 (13.91)	3.22 (10.41)
45	2.57 6.63	2.47 (6.11)	3.01 (9.08)	2.86 (8.18)	3.32 (11.03)	3.17 (10.07)	3.55 (12.63)	3.42 (11.72)

Comparisons

1. Two sprouting durations at the same cultivar:

	30th	40th	50th	60th
a. S.Em±	0.04	0.04	0.04	0.03
b. CD at 5%	0.11	0.11	0.11	0.10

2. Two cultivars at the same or different duration(s) of sprouting:

	30th	40th	50th	60th
a. S.Em±	0.04	0.04	0.03	0.03
b. CD at 5%	0.12	0.10	0.10	0.10

Duration of sprouting (days)	Days of storage period 70th V1	70th V2	80th V1	80th V2	90th V1	90th V2
0	4.21 (17.74)	3.90 (15.25)	4.51 (20.40)	4.23 (17.91)	4.79 (22.96)	4.50 (20.31)
15	3.96 (15.75)	3.64 (13.28)	4.23 (17.94)	3.97 (15.81)	4.50 (20.26)	4.24 (18.04)
30	3.98 (15.85)	3.42 (11.72)	4.29 (18.44)	3.76 (14.16)	4.56 (20.81)	4.01 (16.14)
45	3.78 (14.30)	3.66 (13.44)	4.08 (16.70)	3.98 (15.89)	4.33 (18.82)	4.25 (18.06)

Comparisons

1. Two sprouting durations at the same cultivar:

	70th	80th	90th
a. S.Em±	0.03	0.03	0.03
b. CD at 5%	0.10	0.10	0.10

2. Two cultivars at the same or different duration(s) of sprouting:

	70th	80th	90th
a. S.Em±	0.03	0.04	0.03
b. CD at 5%	0.09	0.11	0.10

*Figures within parentheses indicate original values

Table 28. Effect of ducation of sprouting, date of planting and cultivar on rottage during storage

Treatment	Day of storage period						
	30th	40th	50th	60th	70th	80th	90th
Duration of sprouting (days)							
0	1.92 (3.68)*	2.68 (7.18)	3.22 (10.36)	3.51 (12.36)	3.81 (14.54)	4.23 (17.92)	4.61 (21.31)
15	1.81 (3.27)	2.51 (6.35)	3.03 (9.18)	3.29 (10.87)	3.56 (12.72)	4.01 (16.12)	4.37 (19.11)
30	1.63 2.65	2.34 5.47	2.85 8.12	3.06 9.41	3.29 10.82	3.72 13.88	4.06 16.55
45	1.51 (2.28)	2.17 (4.70)	2.65 (7.02)	2.77 (7.67)	3.04 (9.24)	3.47 (12.07)	3.82 (14.63)
S.Em±	0.02	0.02	0.02	0.03	0.03	0.04	0.04
CD at 5%	0.06	0.06	0.06	0.07	0.09	0.11	0.10
CV (%)							
Date of planting							
January 25	1.65 (2.72)	2.36 (5.56)	2.85 (8.32)	3.03 (9.19)	3.30 (10.90)	3.73 (13.94)	4.09 (16.74)
February 9	1.78 (3.16)	2.49 (6.20)	3.03 (9.18)	3.29 (10.84)	3.55 (12.63)	3.98 (15.90)	4.34 (18.91)
S.Em±	0.03	0.02	0.03	0.03	0.04	0.03	0.03
CD at 5%	0.11	0.08	0.09	0.11	0.12	0.10	0.10
CV (%)							
Cultivar							
QB/A-9-120	1.82 (3.31)	2.57 (6.60)	3.11 (9.67)	3.39 (11.49)	3.68 (13.58)	4.11 (16.89)	4.45 (19.87)
Kufri Jyoti	1.61 (2.59)	2.28 (5.19)	2.76 (7.61)	2.93 (8.62)	3.16 (10.04)	3.61 (13.07)	3.98 (15.87)
S.Em±	0.03	0.02	0.03	0.03	0.04	0.03	0.03
CD at 5%	0.11	0.08	0.09	0.11	0.12	0.10	0.10
CV (%)							

*Figures within parentheses indicate original values

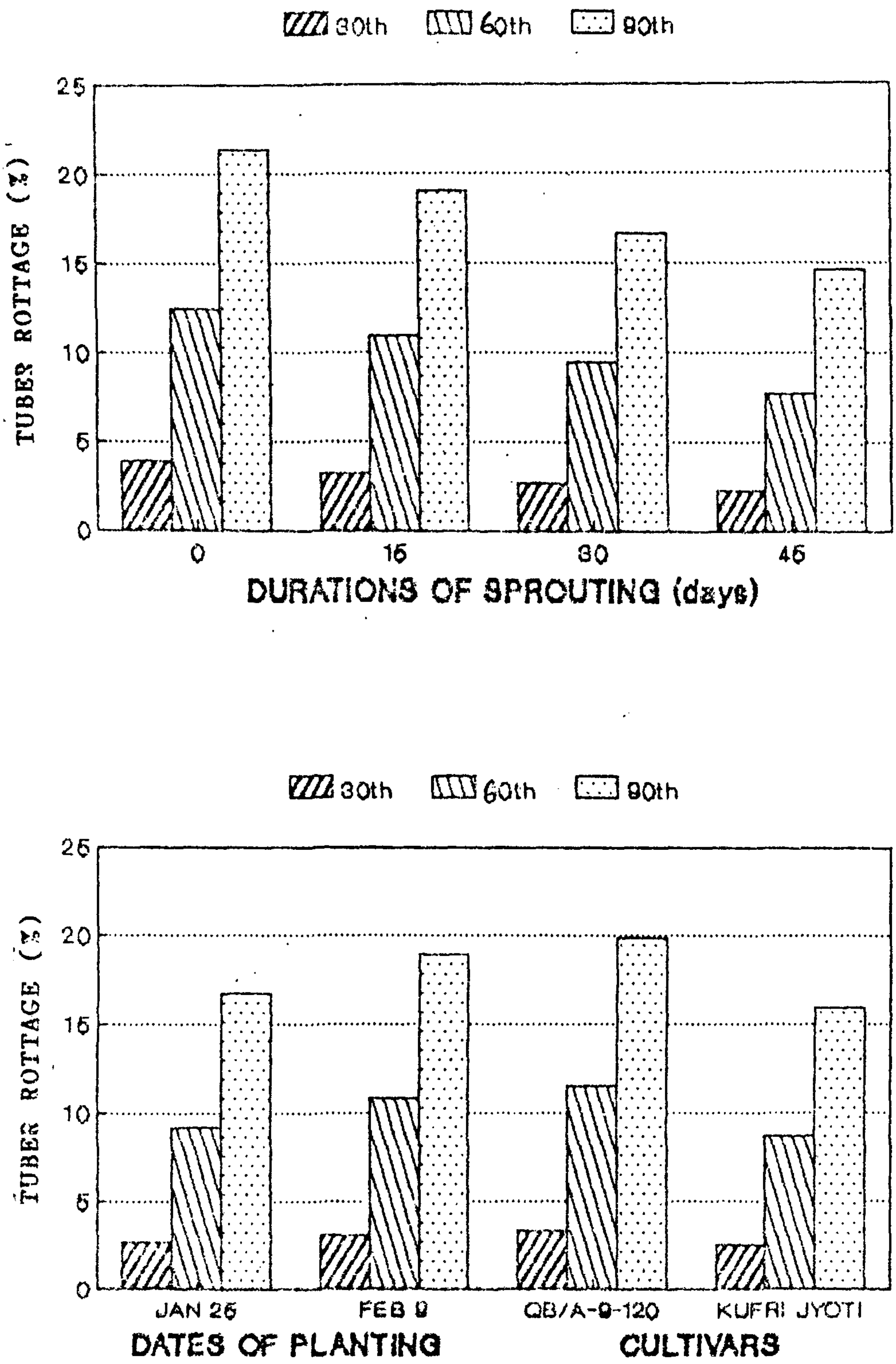


FIG.14 EFFECT OF SPROUTING DURATIONS, PLANTING DATES AND CULTIVARS ON TUBER ROTTAGE (%) ON 30th, 60th AND 90th DAY OF STORAGE

significantly higher values of cumulative moisture loss at all the durations of sprouting on 40th, 50th, 60th and 70th day of storage. The trend was similar in respect of other observations (30th, 80th and 90th day) except the moisture loss under S_4 treatment in both cultivars was statistically similar.

4.7.2 Cumulative rottage

The data presented in Table 28 revealed that the cumulative rottage decreased significantly and consistently with increase in duration of sprouting from S_1 to S_4 at all the dates of observation. Consequently maximum and minimum rottage loss was observed in S_1 and S_4 treatments, respectively. Rottage was significantly lower in P_1 as compared to P_2. In respect of cultivars, rottage loss was significantly lower in Kufri Jyoti than QB/A-9-120.

4.7.3 Sprouting percentage

The effect of experimental factors on tuber sprouting percentage under storage was significant at all the dates of observation (Table 29). Significantly highest tuber sprouting was recorded in 45 days sprouting duration treatment. Significant and consistent decrease in sprouting with increase in duration of sprouting was observed upto 70th day of storage. However, at later observations, the difference in tuber sprouting between S_3 and S_4 was not significant. In respect of date of planting, the tuber sprouting was significantly lower in P_2 (9th February) compared to P_1

Table 29. Effect of duration of sprouting, date of planting and cultivar on tuber sprouting during storage

Treatment	Day of storage period						
	30th	40th	50th	60th	70th	80th	90th
Duration of sprouting (days)							
0	1.36 (1.85)*	1.98 (3.92)	2.41 (5.84)	2.79 (7.78)	3.17 (10.04)	3.73 (13.98)	4.26 (18.16)
15	1.49 (2.24)	2.11 (4.45)	2.65 (7.02)	2.97 (8.82)	3.36 (11.28)	3.99 (15.92)	4.49 (20.20)
30	1.64 (2.70)	2.32 (5.38)	2.80 (7.87)	3.15 (9.92)	3.54 (12.53)	4.17 (17.38)	4.73 (22.40)
45	1.71 (2.95)	2.40 (5.76)	2.85 (8.14)	3.16 (9.98)	3.60 (12.96)	4.17 (17.38)	4.72 (22.34)
S.Em±	0.02	0.02	0.01	0.01	0.01	0.03	0.03
CD at 5%	0.06	0.07	0.04	0.03	0.03	0.08	0.10
CV (%)	4.26	3.76	1.86	1.29	1.15	2.36	0.76
Date of planting							
January 25	1.64 (2.71)	2.29 (5.24)	2.77 (7.72)	3.18 (10.11)	3.62 (13.10)	4.22 (17.88)	4.82 (23.26)
February 9	1.46 2.14	2.12 4.49	2.58 6.68	2.85 8.12	3.21 10.30	3.81 14.52	4.28 18.36
S.Em±	0.03	0.03	0.03	0.03	0.02	0.02	0.03
CD at 5%	0.12	0.11	0.09	0.09	0.08	0.08	0.09
CV (%)	10.73	7.33	5.00	4.51	3.53	2.95	2.94
Cultivar							
QB/A-9-120	1.43 (2.06)	2.09 (4.36)	2.50 (6.28)	2.86 (8.17)	3.22 (10.36)	3.79 (14.37)	4.34 (18.87)
Kufri Jyoti	1.67 (2.80)	2.32 (5.38)	2.65 (8.16)	3.17 (10.04)	3.62 (13.10)	4.24 (18.05)	4.76 (22.69)
S.Em±	0.03	0.03	0.03	0.03	0.02	0.02	0.03
CD at 5%	0.12	0.11	0.09	0.09	0.08	0.08	0.09
CV (%)	10.73	7.33	5.00	4.51	3.53	2.95	2.94

*Figures within parentheses are original values

(25th January). Between cultivars, significantly lower tuber sprouting was observed in QB/A-9-120 than Kufri Jyoti.

The interaction effect between duration of sprouting and cultivars significantly influenced the sprouting percentage of tubers at all the dates of observation (Table 30) . In cultivar QB/A-9-120, higher sprouting percentage was recorded in S_4 which decreased significantly and consistently with decrease in duration of sprouting and lowest tuber sprouting was observed in control treatment (S_1). In Kufri Jyoti, S_3 treatment recorded significantly higher sprouting percentage of tubers than the remaining sprouting durations at all stages of observation except at 30th and 40th day of storage when S_3 remained at par with S_4 treatment. Significantly lowest tuber sprouting was observed in no sprouting treatment. In general, S_2 remained at par with S_4. However, this treatment recorded significantly lower tuber sprouting at 40th and 90th day of storage. In respect of tuber sprouting response of cultivars to a given duration of sprouting, it was observed that Kufri Jyoti recorded significantly higher sprouting percentage than QB/A-9-120 at S_1, S_2 and S_3 sprouting durations. Similar trend was observed in S_4 except in initial stages (upto 60 days) when the tuber sprouting in both the cultivars was statistically similar.

Table 30. Interaction effect between durations of sprouting and cultivars on tuber sprouting (%) during storage

Duration of sprouting (days)	Cultivar							
	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2
	Day of storage period							
	30th		40th		50th		60th	
0	1.22	1.49	1.84	2.12	2.21	2.63	2.60	2.98
	(1.49)*	(2.24)	(3.40)	(4.53)	(4.88)	(6.92)	(6.80)	(8.91)
15	1.31	1.68	1.96	2.27	2.43	2.87	2.77	3.18
	(1.71)	(2.85)	(3.85)	(5.18)	(5.94)	(8.24)	(7.70)	(10.15)
30	1.51	1.77	2.19	2.47	2.57	3.05	2.95	3.35
	(2.30)	(3.14)	(4.80)	(6.11)	(6.60)	(9.30)	(8.76)	(11.23)
45	1.69	1.74	2.38	2.42	2.80	2.90	3.13	3.19
	(2.86)	(3.04)	(5.67)	(5.90)	(7.87)	(8.41)	(9.81)	(10.23)

Comparisons

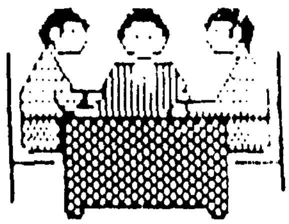
	30th	40th	50th	60th
1. Two sprouting durations at the same cultivar:				
a. S.Em±	0.03	0.03	0.02	0.02
b. CD at 5%	0.08	0.10	0.05	0.06
2. Two cultivars at the same or different duration(s) of sprouting:	0.04	0.04	0.03	0.03
a. S.Em±	0.04	0.04	0.03	0.03
b. CD at 5%	0.13	0.14	0.10	0.09

Duration of sprouting (days)	Days of storage period					
	70th		80th		90th	
0	2.94	3.41	3.47	4.00	4.03	4.48
	(8.70)	(11.63)	(12.06)	(16.04)	(16.30)	(20.11)
15	3.11	3.62	3.71	4.26	4.23	4.75
	(9.70)	(13.10)	(13.78)	(18.21)	(17.96)	(22.75)
30	3.30	3.79	3.91	4.44	4.48	4.98
	(10.93)	(14.40)	(15.31)	(19.71)	(20.08)	(24.85)
45	3.54	3.67	4.06	4.27	4.61	4.83
	(12.54)	(13.51)	(16.51)	(18.28)	(21.32)	(23.37)

Comparisons

	70th	80th	90th
1. Two sprouting durations at the same cultivar:			
a. S.Em±	0.02	0.04	0.02
b. CD at 5%	0.05	0.11	0.05
2. Two cultivars at the same or different duration(s) of sprouting:			
a. S.Em±	0.03	0.03	0.03
b. CD at 5%	0.10	0.10	0.10

*Figures within parentheses indicate original values.



DISCUSSION

5. DISCUSSION

The results emanating from the experiment "Studies on the effect of period of sprouting and date of planting on productivity, quality and storage behaviour of potato" have been presented in the preceding chapter with the help of data tables and various illustrations. In this chapter efforts have been made to interpret the important results of the present investigation by establishing the cause and effect relationship on the basis of available evidences. For convenience the findings have been discussed under different headings.

It is evident from the yield data embodied in Table 20 that highest tuber yield (186.6 q ha^{-1}) obtained in the present studies was well below the optimum for this commercial crop. A perusal of weather data depicted in Figure 1 and appended in Appendix I revealed that no weather element was so adverse for the optimum growth and development of this crop except during emergence and initial growth stages (upto 1st April) when the mean temperatures were not conducive for potato crop and which consequently were reflected in long time taken by potato for the emergence (75%) and tuberization. Hence, there have been extraclimatic factors which influenced the general yield level in the present experiment. Silty clay loam texture of the experimental site might be regarded as number one factor for the low yield of potato under Kangra valley conditions as the crop is best grown on light soils with high amounts of organic matter. Secondly, the crop did not receive irrigations as frequently as desired because only four irrigations could be applied to the crop. For high yields, potato requires 8-10 irrigations in this area. In addition, the crop was also infected heavily by bacterial wilt and in some treatments the disease incidence was as high as 65.8% (Table 4). Hence, below optimum tuber yield.

5.1 Effect of durations of sprouting

The durations of sprouting influenced all the growth parameters of potato significantly. Plant population was significantly higher in 45 (S_4) and 30 (S_3) days sprouting duration which decreased with further decrease in duration of sprouting to 15 days (S_2) or no sprouting treatment (S_1) at tuber initiation and harvest. Data contained in Table 3 indicated that the proportion of seed tubers showing measurable sprout growth ($\geq$3mm) was much higher in S_4 and S_3 (54.5 and 49.5%) than S_2 and S_1 treatments (40.5 and 26.0%). This coupled with increased number of sprouts/sprouted tuber might have contributed significantly towards increased plant population in S_4 and S_3 especially under the agroecological conditions of Kangra valley where texturally, soils are not very conducive for optimum plant emergence. There is formation of hard crust at the soil surface which influences the plant emergence adversely. The decrease in plant population at harvest compared with that at tuber initiation especially in S_1 and S_2 treatments confirms to the natural phenomenon of plant senescence towards crop maturity. Incidence of wilt might also have further accelerated the senescence process. The decrease in plant population in S_4 and S_3 at harvest was not as pronounced as in S_1 and S_2. This was probably due to reduced incidence of wilt in S_4 and S_3 treatments than S_1 and S_2 treatments (Table 4).

The plant height in no sprouting treatment (S_1) was significantly highest compared with all other durations of sprouting (Table 5). The difference between 30 (S_3) and 45 days (S_4) sprouting durations in this respect was not significant. This perhaps happened because of higher lateral growth and increased vigour of plants in S_3 and S_4 treatments as evidenced by increased number of stems/plant and LAI (Table 7) in these treatments compared with other two durations of sprouting viz., 15 days (S_2) and no sprouting (S_1). The main reason for higher values of stems/plant and LAI appear to be higher number of sprouts/sprouted tuber vis-a-vis their increased length under S_3 and S_4 compared with S_1 and S_2 treatments (Table 3). There was a decrease in LAI at harvest compared with the LAI at tuber initiation stage (Table 7) because of lower plant population and is in agreement with decreased plant growth at the respective growth stages and also increased leaf senescence at harvest.

Successive durations of sprouting brought a significant decrease in the number of days required for attainment of 75% plant emergence, stolonization as well as tuber initiation stages over the preceding sprouting duration. The maximum sprouting duration of 45 days (S_4) helped in attaining 75% emergence, stolonization and tuber initiation stages 4.5, 5.3 and 4.6 days earlier than S_1 treatment, respectively. Such types of results could be expected given that 45 days sprouting duration had resulted in longer sprouts (3.8mm) on seed tubers compared with S_1 treatment (3.1mm) which in turn, resulted in growth advantage in S_4 treatment from the planting stage itself. Early plant emergence and early tuberization due to sprouted seed tubers have also been reported by Jain and Sinha (1982) and Sinha (1974).

Different durationsof sprouting influenced the total tuber yield significantly (Table 20). Successive increase in duration of sprouting increased the tuber yield over its preceding level. Thus, maximum tuber yield (119.91 q. ha^{-1}) was recorded in 45 days (S_4) sprouting duration and minimum (64.58 q ha^{-1}) in control (S_1). This 85.7 per cent increase in tuber yield in S_4 over S_1 is perhaps the consequence of its better influence on growth parameters such as LAI and stems/plant (Table 7) which in turn, lead to better development of yield attributes (Table 17). Early tuber initiation in 45 days sprouting duration lead to increased time availability from tuber initiation to harvest stage and thus, paved the way for better development of yield attributes viz., per plant number of tubers and fresh and dry weights of tubers resulting in their higher values in S_4 compared to S_1 treatment. Higher plant height (Table 5) which is negatively correlated to potato yield (Caliskan and Incekara, 1987) might have also widened the yield gap further. There was also an increased bacterial wilt incidence in S_1 which might have brought further yield reductions in this treatment. Marinis (1978) and Kondratowicz and Paprocki (1985) also reported higher tuber yields from seed tubers planted after sprouting as compared to when seed tubers were planted without sprouting. Similarily, Banerjee et al. (1978) found that sprouting seed tubers for three weeks gave higher yields than sprouting for one week or no sprouting.

Since, the potato crop was healthier and more vigorous in S_3 amd S_4 treatments as evidenced by higher number of stems/plant and higher LAI than S_1 and S_2 treatments, therefore, all quality aspects viz., contents of dry matter, starch and protein as well as specific gravity were significantly higher in S_3 and S_4 sprouting durations compared to S_1 and S_2. Similar results have also been reported by Furunes (1990), Kondratowicz and Paprocki (1982 and 1985) and Szysz and Songin (1987).

Durations of sprouting were also found to influence potato during storage and significantly lower values of moisture and rottage losses were observed in 45 days sprouting duration treatment compared to all other durations of sprouting. Significantly highest losses were recorded in no sprouting treatment. Since, the potato crop in S_4 treatment tuberized 4.8 days earlier than in S_1 treatment, this increased the time availability for the tuber bulking phase and thus, indirectly helped in proper maturity of tuber and tuber periderm. Such matured tubers have less susceptibility to injury and hence, rottage losses. Moisture loss from the matured tubers is also less compared to that from comparatively less matured tubers. Similar results have been reported by Burton (1957) and Singh (1957). Contrarily, the sprouting percentage of stored tubers was significantly higher in S_4 treatment than other durations of sprouting probably due to better tuber curing in this treatment.

5.2 Effect of dates of planting

Dates of planting affected the growth, development, yield attributes and yield as well as quality and storage behaviour of potato significantly. The delay in planting from 25th January (P_1) to 9th February (P_2) resulted in significantly taller plants at tuber initiation as well as at harvest stage (Table 5). The difference in plant height between P_1 and P_2 planting dates was not significant at stolonization stage. In addition to genetic control, plant height is also influenced by weather elements, especially temperature. The mean phasic temperature from planting to stolonization was almost similar for P_1 and P_2 plantings (13.5 and 12.3 °C, respectively) and hence, resulting in similar plant height at this stage. However, the mean temperatures from planting to tuber initiation and planting to harvest stages for P_1 were 12.7 and 20.8 °C. The corresponding temperatures for P_2 planting were 14.8 and 22.2 °C. These mean temperature variations convincingly describe the observed difference in the height of plants in the two planting dates. Similar increases in plant height with delay in planting during the spring season have also been reported by Khalel et al. (1986). Number of stems/plant which in potato is mainly a function of the number of eyes/seed tuber was expectedly not influenced in the two planting dates significantly (Table 7) since each seed tuber for planting was ensured almost equal number of eyes (2 to 3). Similarly, plant population was also not influenced significantly due to the planting dates. The results are in conformity with those of Roztropowics and Wardzynska (1975). Values of LAI were significantly higher in 9th February planting(P_2) compared to 25th January planting (P_1). The higher value of LAI with delayed planting in spring season might be due to thermo photoperiodicity effect and conforms to the pattern of mean temperature experienced by different crop stages in the two planting dates. These results confirm, albeit, indirectly the findings of Borah and Milthorpe (1962) and Roztropowics and Wardzynska (1975) who reported growth acceleration in potato due to late planting.

All phenological stages viz., 75 per cent emergence, stolonization and tuber initiation stages were attained significantly earlier in delayed planting (9th February) than early planting (25th January) (Table 10) and are explained on the basis of higher mean temperatures prevailing at various growth stages of late planted crop. In a photosensitive crop like potato, attainment of a particular phenological stage depends on whether or not, the crop has been subjected to a certain minimum number of growing degree days (summation of daily mean temperature – base temperature (crop specific) upto that stage. Hence, higher mean temperature would meet the degree day requirement of a given phenophase over a shorter time span and same appears to have operated in respect of delayed planting (P_2) which recorded all phenological stages earlier than early planting (P_1). Faster plant growth and earlier tuberization with late plantings have also been reported by Demaganate and Vander (1988). Similarly, Borah and Milthorpe (1962), Mckeown (1987), Rashid and Ali (1992) and Sinha and Rai (1982) also reported that emergence, tuber initiation and subsequent growth were faster at high temperature.

The data presented in Table 13 reveal that the number of tubers/plant was not influenced significantly due to non-significant effect of planting dates on the number of stems/plant, since the number of tubers/plant within certain limits is a function of number of above ground stems/plant (Wiersema, 1987). The fresh and dry weight of tubers/plant was, however, significantly higher in P_1 planting over P_2 date of planting on each date of sampling. Growth rate in respect of fresh weight of tubers/plant depends largely on the mean night temperature during the post tuberization phase (Banerjee, 1983). A critical examination of the mean minimum temperature revealed that its value during the first 50 days of tuberization ranged from 17.9°C in P_2 to 15.5°C in P_1 planting and this explains the effects of planting dates on the tuber fresh weight/plant on one hand and the tuber dry weight on the other, since the latter (dry weight) depends largely on the former (fresh weight).

Tuber yield was significantly higher in P_1 planting than P_2 planting (Table 20). Plant population and per plant tuber yield are the main components of total yield/unit area in potato. Though plant population (Table 5) and tubers/plant (Table 17) were statistically similar in the two dates of planting, yet fresh weight of tubers/plant was significantly higher in P_1 than P_2 at all dates of observation and this parameter (tuber fresh weight/plant) probably contributed most towards higher tuber yield of crop under P_1 planting. It may be argued that tuber yield has been low in P_2 planting inspite of the higher values of LAI in this planting date. But shorter tuber bulking period under P_2 planting might have been another important factor for low tuber yield in this treatment, as the crop in P_2 was planted 15 days after P_1 but harvested on the same day. Decrease in yields with delay in planting have also been reported by Lal and Sahota (1983), Matlob and Mahmood (1984), Perumal (1981) and Rashid and Ali (1992).

The tuber dry matter yield exhibited a trend similar to the total tuber yield which was higher in first planting than the second date of planting. Further, examination of the data in Table 20 revealed that the production of 'B' and 'D' grade potato tubers was significantly lower in second date of planting as compared to first date of planting. Further, the values of yields in grades 'A' and 'C', though, lower in P_2 than P_1 planting, were not significantly different from one another. Obviously, the gradewise tuber yield depends upon the total tuber yield which was significantly lower in P_2 compared with P_1 planting.

The dates of planting influenced the dry matter content significantly and the contents were higher in earlier planting as compared to delayed planting. Since, the crop in early planting got approximately 12 days more than late planting from tuber initiation to harvest stage, it might have favourably influenced the dry matter content in its produce. The results are in conformity with the findings of Kondratowicz and Paprocki (1982). Similarly, Ronsen and

Ekeberg (1984) reported that dry matter content decreased 0.1% for each days' delay in planting time. The planting dates failed to influence the starch and protein contents as well as specific gravity of the potato produce.

The moisture loss increased consistently with increase in duration of storage (Table 26). The higher moisture loss (%) was observed in delayed planting as compared to early planting. Similar trend was observed in respect of tuber rotting. The results are, again explained on the basis of availability of 12 days extra time for early planted crop (P_1) from tuber initiation to harvest stage which might have helped in proper maturity of tuber as well as tuber periderm. In contrast to the effects of date of planting on moisture loss and tuber rottage, the sprouting percentage in stored tubers was significantly higher in the produce obtained from first planting compared to that from second planting in which case the onset of tuberization was delayed and the tubers were probably, immature at harvest stage. Similar results have been reported by Burton (1957) and Singh (1957) also.

5.3 EFFECT OF CULTIVARS

Potato cultivars differed between each other significantly in respect of growth and development, yield attributes, yield and quality as well as storage behaviour of potato. The data presented in Table 5 revealed that the plants of QB/A-9-120 were significantly taller than Kufri Jyoti. In addition, the LAI was also significantly (29.9%)

higher in this cultivar compared with Kufri Jyoti indicating that the plants of QB/A-9-120 are more vigorous and stout compared with plants of Kufri Jyoti. The effect of cultivars on plant population (Table 5) and stems/plant (Table 7) was not significant. Since, the potato crop is raised from seed tubers each having 2-3 eyes, the percentage plant population in this crop is generally higher. Stems/plant is a genetically controlled character and agronomic management can exert its influence on this parameter only to a limited extent. Hence, the two cultivars seem to have approximately similar number of stems/plant.

All phenological stages were attained significantly earlier in variety Kufri Jyoti compared with QB/A-9-120. The difference between the two cultivars for emergence (75%), stolonization and tuber initiation was 3.6, 2.6 and 9.6 days, respectively which indicated that QB/A-9-120 may not be a suitable cultivar in comparison to Kufri Jyoti under the agroecological conditions of Kangra Valley of Himachal Pradesh as time availability from tuber initiation to crop maturity in this cultivar is drastically reduced. Since the number of tubers/plant in Kufri Jyoti was significantly higher than QB/A-9-120 (Table 13), therefore the tuber fresh as well as dry weights were significantly higher in this variety than QB/A-9-120 at all stages of observation. Similar trend between the two cultivars was observed in respect of yield attributes at harvest stage.

Total tuber yield of Kufri Jyoti was significantly higher (145%) than QB/A-9-120. Likewise, the yield of tubers in different grades was also higher. Increased availability of time for tuber bulking due to early tuber initiation and decreased bacterial wilt incidence in Kufri Jyoti might be held responsible for higher tuber yield of Kufri Jyoti compared to QB/A-9-120. Higher values of yield attributes particularly average tuber weight and tuber fresh weight/plant in Kufri Jyoti might also have been responsible for higher tuber yield of this variety. Tuber dry matter content (%) being higher in Kufri Jyoti resulted in significantly higher tuber dry matter yield of this variety. Significantly, cultivar QB/A-9-120 recorded higher protein content than Kufri Jyoti.

The data on storage aspects was significantly influenced due to the potato cultivars. Moisture as well as rottage losses which increased with increase in duration of storage were significantly higher in QB/A-9-120 compared with Kufri Jyoti (Tables 26 and 28). Further, glance at data in Table 10 revealed significant difference between the two cultivars in respect of time taken for tuber initiation stage, with QB/A-9-120 attaining the stage 9.6 days after Kufri Jyoti which probably resulted in tubers with poorly cured skin rendering the potatoes highly vulnerable to injury and consquently increasing their susceptibility to moisture and rottage losses. Immature tubers of QB/A-9-120 showed susceptibility to moisture and rottage losses. Immature tubers of QB/A-9-120 showed much less tuber sprouting as compared to Kufri Jyoti. Similarly, Emilson (1949), Martin et al. (1925) and Wilson et al. (1962) reported that cultivars differed markedly in their rate of sprout growth.

5.4 EFFECT OF INTERACTIONS

Since, higher tuber yield is the main objective of potato cultivation, hence, attempts have been made to discuss the interaction effect between various experimental factors on this important parameter. A perusal of the data in Table 23 revealed that irrespective of date of planting, the tuber yield decreased significantly and consistently in QB/A-9-120 with decrease in duration of sprouting from 45 to 15 days. Further decrease in sprouting duration did not decrease the yield (Table 23). However, in Kufri Jyoti various sprouting durations ranked in the order $S_1<S_2<S_4<S_3$ in this respect. Further comparisons revealed that early planting of Kufri Jyoti (on 25th January) resulted in significantly higher yield than that from late planting (9th February), the latter in turn, was also better than QB/A-9-120 planted on either date in S_1, S_2 and S_3 sprouting duration treatments. In 45 days sprouting duration treatment, variety Kufri Jyoti planted on first date remained at par with its planting on second date. However, in QB/A-9-120, planting on 25th January was superior to that of 9th February.

For explaination of the pattern of tuber yield a critical examination of the data contained in Tables 14 and

16 becomes essential. The data reveals (Table 14) that at all stages of observation number as well as fresh weight of tubers/plant in QB/A-9-120 was significantly higher in 45 days compared to all other durations of sprouting. The trend was similar in data recorded on 60th day of tuber initiation (Table 16). In Kufri Jyoti, number of tubers as well as tuber fresh weight per plant were significantly higher in 30 days sprouting duration than all other durations of sprouting. Thus, the observed trends in yield of the two cultivars have been fully justified by the data on progressive tuber development.

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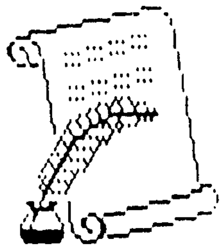

SUMMARY

6. SUMMARY AND CONCLUSIONS

The present study entitled "Studies on the effect of period of sprouting and date of planting on productivity, quality and storage behaviour of potato" was undertaken at the Research Farm, Department of Vegetable Science and Floriculture, Himachal Pradesh, Krishi Vishvavidyalaya, Palampur during spring 1993. The main objectives of the investigation were:

- to study the effect of seed potato sprouting on growth, yield and yield attributes vis-a-vis its influence on storage aspects viz., moisture loss and rottage as well as tuber sprouting. The study also aimed at standardising the optimum time of planting for the two potato cultivars viz; QB/A-9-120 and Kufri Jyoti under agroecological conditions of Kangra Valley of Himachal Pradesh.

To meet out the objectives, treatments were selected as below:

1. Durations of sprouting : 4 (0,15,30 and 45 days)
2. Dates of planting : 2 (25th January and 9 February)
3. Cultivars : 2 (Kufri Jyoti and QB/A-9-120)

The experiment was laid out in a split plot design and replicated three times. Combinations of date of planting and cultivar were assigned to main plots and duration of sprouting to subplots. The crop was fertilized uniformly using 120 kg N, 80 Kg P_2O_5 and 60 kg K_2O/ha, respectively. In addittion, 20t/ha well rotten farm yard manure was also applied at the time of planting. The crop was harvested on June, 12.93.

In this chapter, the important experimental finding have been summarised.

6.1 EFFECT OF DURATIONS OF SPROUTING

1. The growth parameters viz., plant population, plant height, stems/plant and leaf area index were influenced significantly by durations of sprouting. Values of all these parameters except plant height were significantly higher in 45 days (S_4) and 30 days (S_3) sprouting duration treatments, which were at par with each other compared to 15 days (S_2) and no sprouting (S_1) treatments at all stages of observation viz., stolonization, tuber initiation and harvest. However, plant height was significantly higher in S_1 and S_2 treatments than S_3 and S_4 treatments.

2. Emergence (75%), stolonization and tuber initiation required significantly more number of days in no sprouting (S_1) treatment as compared to S_3 and S_4 sprouting durations. The difference between S_4 and S_3 in this respect was not significant.

3. Phasic tuber development was also influenced significantly by durations of sprouting. Number of

tubers/plant and tuber fresh and dry weights/plant increased significantly and consistently with increase in duration of sprouting from 0 to 30 days at all stages of observation. Further increase in duration of sprouting to 45 days did not improve the number of tubers/plant as well as tuber fresh and dry weights/plant.

4. The various yield attributes viz., number of tubers/plant and tuber fresh and dry weights/plant were significantly higher in S_4 and S_3 compared to S_2 and S_1 treatments. The difference between S_4 and S_3 treatments, however, was not significant.

5. Duration of sprouting influenced the tuber yield of potato significantly (Table 20). The yields in grades 'A', 'B' and 'C' as well as total tuber yield were significantly higher in 45 days sprouting duration treatment as compared to all other sprouting durations. In respect of grade 'D' tuber yield 30 days sprouting duration significantly out performed the 45 days sprouting duration. Lowest yields in all grades were recorded in no sprouting treatment.

6. Quality parameters were significantly higher in S_4 than S_2 and S_1 sprouting durations. Treatments S_4 and S_3 and S_2 and S_1, however, behaved statistically alike among themselves.

7. The effect of durations of sprouting on storage aspects was found to be significant. Moisture as well rottage losses were significantly lower in S_4 and S_3 treatments which remained at par with each other. Highest losses were observed in S_1 treatment. Tuber sprouting duration during storage was, however, significantly higher in S_4 treatment whereas, it was lowest in no sprouting treatment.

6.2 EFFECT OF DATES OF PLANTING

1. The plant population and stems/plant were not influenced significantly by dates of planting. However, the plant height was significantly lower in 25th January planting date (P_1) compared to 9th February (P_2) at tuber initiation and harvest stages. Similar trend was observed in respect of leaf area index.

2. The number of days required for 75% emergence, stolonization and tuber initiation stages were significantly more in P_1 planting compared to P_2 planting.

3. Number of tubers/plant at various stages of observation was not influenced significantly by dates of planting. However, the tuber fresh as well as dry weights/plant were significantly higher in P_1 planting than P_2 planting. Similar results were recorded at harvest stage.

4. Tuber yield in grades 'B' and 'D' as well as total tuber yield and tuber dry matter yield were significantly higher in early planting (P_1) compared to delayed planting (P_2).

5. Tuber dry matter content was significantly higher in P_1 planting than P_2 planting. Other quality parameters viz., starch content, protein content and specific gravity were statistically similar in both planting dates.

6. Storage losses (moisture as well as tuber rotting) were significantlylower in first date of planting compared to second date of planting. However, tuber sporuting during storage was significantly lower in P_2 compared to P_1.

6.3 EFFECT OF CULTIVARS

1. Both cultivars viz.,QB/A-9-120 and Kufri Jyoti did not differ significantly between each other in respect of plant population and number of stems/plant. However, plant height as well as LAI were significantly higher in QB/A-9-120 than Kufri Jyoti at tuber initiation and harvest stages.

2. Cultivar QB/A-9-120 took significantly longer time to attain 75% emergence, stolonization and tuber initiation stages compared to Kufri Jyoti.

3. Number of tubers/plant as well as fresh and dry weights of tubers/plant were significantly higher in Kufri Jyoti compared to QB/A-9-120 at all stages of

observation. Similarly, all yield attributes recorded significantly higher values in Kufri Jyoti compared to QB/A-9-120.

4. Gradewise as well as total tuber yield and tuber dry matter yield were significantly higher in Kufri Jyoti than QB/A-9-120.

5. Dry matter content (%) was significantly higher in Kufri Jyoti than QB/A-9-120. However, protein content was significantly higher in QB/A-9-120 compared to Kufri Jyoti. The cultivars did not differ significantly between each other in respect of starch content and specific gravity.

6. Storage losses (moisture as well as rotting) were significantly lower in Kufri Jyoti compared to QB/A-9-120 at all stages of observation. Tuber sprouting during storage however, was significantly higher in Kufri Jyoti.

CONCLUSIONS

On the basis of one year investigations following conclusions have been drawn:

1. Planting potato on 25th January is better than planting on 9th February as with delay in planting there is drastic reduction in the yield of tubers.

2. In view of the low tuber yield, cultivar QB/A-9-120 does not appear to be promising in comparison to variety Kufri Jyoti under the agroecological conditions of Kangra valley of Himachal Pradesh.

3. For higher yields, seed tubers of Kufri Jyoti may be given a sprouting duration [illegible] [illegible] of 30 days whereas, in QB/A-9-120, the seed tubers be sprouted for 45 days.

4. Moisture and rotting percentage together account for approximately 41 and 34 per cent losses in tuber yield of cultivars QB/A-9-120 and Kufri Jyoti, respectively in ninety days storage period. Both, moisture and rotting percentage losses are significantly less in the tuber yield obtained from 45 days sprouting duration treatment compared with 30, 15 and no sprouting duration treatments.

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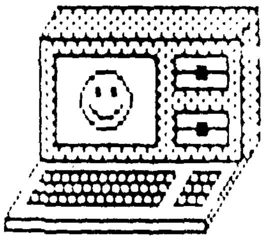

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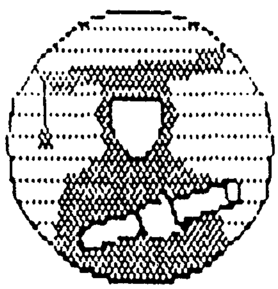

APPENDICES

APPENDIX-I

Mean weekly meteorological data during experimental period (December 1992 to September 1993)

Standard week	Week ending	Temperature(^{o}C) Max.	Min	Relative humidity (%)	Total rainfall (mm)	Sunshine (hrs)	Evaporation (mm)
50	16/12	18.4	7.3	42	-	6.4	1.7
51	23/12	17.7	7.0	38	-	8.3	1.6
52	31/12	17.8	8.1	41	34.0	5.6	2.0
1	7/1	13.0	6.7	65	87.9	1.2	1.3
2	14/1	11.7	3.2	60	12.8	3.5	1.1
3	21/1	12.4	3.7	61	49.8	7.2	1.1
4	28/1	14.5	3.3	47	-	8.5	1.4
5	4/2	17.1	6.8	47	2.4	6.8	1.9
6	11/2	22.3	11.3	49	-	8.5	2.4
7	18/2	21.8	11.1	41	6.8	6.2	2.9
8	25/2	14.3	5.1	54	39.5	6.1	2.1
9	4/3	15.4	7.3	60	9.2	4.6	2.7
10	11/3	21.7	10.2	59	24.8	9.1	2.8
11	18/3	17.6	7.3	67	103.0	5.7	3.4
12	25/3	17.1	8.0	57	133.0	4.4	3.5
13	1/4	17.8	6.9	43	-	8.9	3.7
14	8/4	22.9	11.2	26	-	9.3	4.9
15	15/4	21.9	11.3	46	18.0	6.9	4.7
16	22/4	26.5	14.4	35	-	10.3	5.2
17	29/4	31.2	19.5	30	-	10.8	6.7
18	6/5	28.8	17.6	20	24.0	11.5	8.5
19	13/5	30.8	17.9	37	24.2	8.5	8.6
20	20/5	28.5	17.5	34	56.1	8.3	6.5
21	27/5	32.6	21.2	34	30.0	10.8	8.2
22	3/6	28.7	19.2	57	19.1	8.6	7.1
23	10/6	33.1	23.1	35	1.0	10.8	7.9
24	17/6	31.4	21.3	60	53.6	7.6	7.3
25	24/6	29.7	19.7	71	84.6	8.2	5.7
27	1/7	29.3	19.8	59	28.4	8.3	5.8
27	8/7	28.9	21.8	66	70.4	6.3	5.0
28	15/7	24.0	19.6	82	159.9	2.2	4.6
29	22/7	24.7	19.9	83	160.3	3.1	4.4
30	29/7	25.8	19.0	72	77.2	7.3	4.2
31	5/8	26.4	20.5	77	85.2	4.5	4.4
32	12/8	26.5	19.9	73	80.7	4.4	5.8
33	19/8	29.0	19.8	68	0.2	9.0	4.3
34	26/8	27.2	19.2	74	116.9	8.1	3.4
35	2/9	25.3	19.7	81	108.1	4.4	3.4
36	9/9	24.4	18.0	79	82.5	3.9	2.6
37	16/9	24.3	18.0	76	51.4	4.7	2.6
38	23/9	26.9	18.4	70	3.1	7.5	3.3

APPENDIX-II

Analyses of variance for growth parameters of potato

Source of variation	df	Mean sum of squares — Stage of observation: Stoloni-zation	Tuber initia-tion	Harvest	Stoloni-zation	Tuber initia-tion	Harvest
			A. Plant population (%)		B. Plant height (cm)		
Replication	2		0.3971	0.914	5.990	36.125	47.56
Planting date (P)	1		10.083*	13.65**	1.614	177.5**	1517.62**
Cultivar (V)	1		0.330	30.40**	3.30	730.86**	6190.29**
P x V	1		2.423	0.06	0.22	0.85	213.78
Error(a)	6		1.7631	1.69	0.903	13.22	76.77
Sprouting(S)	3		18.056**	140.84**	10.07**	28.38**	147.63**
P x S	3		2.360	0.66	0.281	2.05	15.84
V x S	3		1.390	19.76**	1.83**	5.39*	25.51*
P x V x S	3		0.360	0.253	0.599	1.99	8.51
Error (b)	24		2.15	2.69	0.295	1.31	7.50
			C. Stems/plant		D. Leaf area index		
Replication	2	0.123	0.016	0.088	0.002	0.0098	0.0359
Planting	1	0.021	0.300	0.047	0.0035	2.1084**	1.0561**
Varieties	1	0.041	0.100	0.200	0.0028	5.6581**	0.806**
P x V	1	0.101	0.007	0.092	0.0001	1.0860**	0.118*
Error (b)	6	0.0267	0.094	0.073	0.0031	0.0236	0.0133
Sprouting	3	0.200*	0.278**	0.156**	0.0024**	0.1950**	0.7646
P x S	3	0.0008	0.020	0.021	0.0005	0.02132**	0.00098
V x S	3	0.038	0.047	0.041	0.0031**	0.0330**	1.0305**
P x V x S	3	0.005	0.011	0.003	0.0003	0.0141*	0.0009
Error (b)	24	0.036	0.021	0.17	0.00044	0.00227	0.02158

APPENDIX-III

Analyses of variance for attainment of phenological stages

Source of variation	df	Mean sum of squares Days taken for Emergence (75%)	Stolonization	Tuber initiation
Replication	2	0.813	0.394	1.560
Planting date(P)	1	13.02**	11.997*	108.0**
Cultivar (V)	1	157.687**	85.330**	1102.08**
P x V	1	0.020	1.336	2.990
Error (a)	6	0.868	1.5351	2.090
Sprouting(S)	3	62.909**	74.9435**	59.40**
P x S	3	0.132	1.278**	0.110
V x S	3	18.687**	9.389**	12.752**
P x V x S	3	0.1319	1.054**	0.223
Error (b)	24	0.465	0.1667	0.293

APPENDIX-IV

Analyses of variance for parameters of tuber development

Source of variation	df	Mean sum of squares Day of tuber initiation 30th	40th	50th
		A. Tubers/plant		
Replication	2	0.295	0.426	1.057
Planting date	1	1.820	0.589	0.518
Cultivar V	1	12.00**	17.112**	39.693**
P x V	1	2.38	7.254*	2.517
Error (a)	6	1.22	0.471	1.0065
Sprouting	3	9.67**	17.636**	19.448**
P x S	3	0.134	0.128	0.076
V x S	3	1.317**	3.736**	3.217**
P x V x S	3	0.452	0.117	0.063
Error (b)	24	0.091	0.1375	0.102

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B. Tubers fresh weight/plant (g)

Replication	2	68.47	535.94	432.18
Planting date	1	3417.19**	1426.44**	3333.33**
Cultivar	1	3669.21**	49088.00	82778.71**
P x V	1	13167.26**	11875.52**	8181.48**
Error (a)	6	47.44	203.61	207.33
Sprouting	3	7356.16**	11108.24**	11172.84**
P x S	3	33.35	139.25	17.59
V x S	3	841.55**	1245.28**	1516.66**
P x V x S	3	171.66	71.04	45.99
Error (b)	24	27.34	49.57	70.33

C. Tubers dry weight/plant (g)

Replication	2	1.78	14.77	15.70
Planting date	1	105.54**	64.38*	107.44**
Cultivar	1	974.67**	1465.09**	2579.86**
P x V	1	381.02**	387.85**	227.13**
Error (a)	6	1.56	9.21	5.92
Sprouting	3	210.41**	354.21**	355.96**
P x S	3	1.58	3.54	0.280
V x S	3	28.15**	48.67**	47.82**
P x V x S	3	4.82	2.62	2.23
Error (b)	24	0.874	11.24	2.63

APPENDIX-V

Analyses of variance for yield attributes

Source of variation	df	Mean sum of squares			
		Average tuber weight (g)	Tubers/plant	Tubers fresh weight/plant (g)	Tubers dry weight/plar (g)
Replication	2	9.734	0.596	421.625	4.263
Planting date	1	59.184*	0.837	3439.00**	91.43**
Cultivar (V)	1	320.85**	97.242**	121703.500**	4455.79**
P x V	1	27.75	3.521	4609.333**	166.51**
Error (a)	6	5.646	0.772	119.069	3.935
Sprouting(s)	3	8.033	15.613**	11079.527**	379.54**
P x S	3	6.398	0.189	20.917	0.864
V x S	3	4.309	3.374**	2016.194**	671.32**
P x V x S	3	0.142	0.231	75.138	5.536
Error (b)	24	3.045	0.174	82.403	2.75

APPENDIX-VI

Analyses of variance for yield of potato (q ha^{-1})

Source of variation	df	Mean sum of squares					
		Grade 'A'	Grade 'B'	Grade 'C'	Grade 'D'	Total tuber yield	Dry matter yield
Replication	2	60.52	42.32	17.71	10.56	221.92	9.22
Planting date	1	1.99	1924.95**	117.31**	64.36*	3763.67**	202.17*
Cultivar	1	5064.14**	8112.26**	7292.95**	1028.78**	7610.33**	3504.64*
P x V	1	4.87	2.10	4.07	31.56*	64.37	2.60
Error (a)	6	8.06	8.144	21.01	5.743	34.96	1.60
Sprouting	3	736.33**	1392.93**	399.76**	84.31**	8117.15**	361.41*
P x S	3	9.91	266.41**	53.63*	23.89	100.85*	5.61*
V x S	3	193.25**	285.45**	282.2**	24.49*	2674.40**	124.90*
P x V x S	3	11.94	62.355*	134.46**	3.970	469.57*	22.766
Error (b)	24	9.92	13.411	6.43	6.184	28.96	1.16

APPENDIX-VII

Analyses of variance for tuber quality parameters

Source of variation	df	Mean sum of squares				
		Dry matter yield	Dry matter content (%)	Starch content (%)	Protein content (%)	Specific gravity
Replication	2	9.22	0.0044	2.109	0.713	0.00022
Planting date (P)	1	202.17**	5.826**	15.729	0.370	0.00011
Cultivar (V)	1	3504.64**	20.28**	0.875	13.275*	0.0006
P x V	1	2.60	1.54**	0.212	0.018	0.0022
Error (a)	6	1.60	0.042	2.789	1.354	0.0012
Sprouting(S)	3	361.41**	0.957**	53.417**	8.293**	0.0019*
P x S	3	5.61**	0.031	0.625	0.519	0.00006
V x S	3	124.90**	0.25*	4.208*	6.215*	0.00013
P x V x S	3	22.766*	0.048	0.381	0.233	0.00017
Error (b)	24	1.16	0.011	0.364	0.529	0.000147

APPENDIX-VIII

Analyses of variance for different storage aspects of potato

Source of variation	df	Mean sum of squares – A. Moisture loss (%) – Day of storage period				
		10th	20th	30th	40th	50th
Replication	2	0.005	0.004	0.056	0.013	0.013
Planting date (P)	1	0.136	0.310	0.547	0.528	0.609
Cultivar (V)	1	0.130**	0.285**	0.683**	1.018**	1.124**
P x V	1	0.022	0.022	0.004	0.003	0.00
Error (a)	6	0.007	0.007	0.008	0.003	0.003
Sprouting (S)	3	0.076**	0.155**	0.202**	0.248**	0.270**
P x S	3	0.005	0.015	0.009	0.015	0.010
V x S	3	0.004	0.015	0.029*	0.036*	0.056
P x V x S	3	0.007	0.020	0.013	0.019	0.021
Error (b)	24	0.009	0.008	0.009	0.009	0.008

		Day of storage period			
		60th	70th	80th	90th
Replication	2	0.007	0.011	0.004	0.002
Planting date	1	0.710**	0.600**	0.552**	0.516**
Cultivar	1	1.200**	1.281**	1.047**	1.34**
P x V	1	0.0004	0.0002	0.000	0.000
Error (a)	6	0.002	0.002	0.004	0.006
Sprouting	3	0.295**	0.323**	0.319**	0.346**
P x S	3	0.010	0.013	0.011	0.123
V x S	3	0.070**	0.098**	0.096**	0.106**
P x V x S	3	0.014	0.011	0.005	0.004
Error (b)	24	0.007	0.008	0.007	0.007

Source of variation	df	Mean sum of squares						
		B. Rottage(%)						
		Day of storage period						
		30th	40th	50th	60th	70th	80th	90th
Replication	2	0.005	0.002	0.003	0.005	0.011	0.010	0.009
Planting date(P)	1	0.192*	0.209**	0.378**	0.820**	0.77**	0.762*	0.79**
Cultivar (V)	1	0.518**	1.024**	1.449**	2.470**	3.21**	2.940*	2.69**
P x V	1	0.049	0.003	0.001	0.002	0.002	0.028	0.050
Error (a)	6	0.025	0.014	0.017	0.025	0.029	0.021	0.021
Sprouting(S)	3	0.413**	0.575**	0.720**	1.223**	1.352**	1.320**	1.43**
P x S	3	0.001	0.001	0.003	0.004	0.003	0.017	0.036
V x S	3	0.019	0.022	0.035	0.065	0.075	0.079	0.046
P x V x S	3	0.004	0.003	0.001	0.001	0.001	0.073	0.050
Error (b)	24	0.005	0.005	0.007	0.008	0.012	0.019	0.015
		C. Tuber sprouting (%)						
Replication	2	0.030	0.042	0.017	0.010	0.008	0.032	0.010
Planting date	1	0.406*	0.354*	0.450**	1.331**	1.941**	2.10**	3.46**
Cultivar	1	0.694**	0.659**	1.471**	1.160**	1.930**	2.52**	2.11**
P x V	1	0.072	0.008	0.009	0.004	0.013	0.070	0.010
Error (a)	6	0.028	0.026	0.018	0.0187	0.015	0.014	0.017
Sprouting	3	0.303*	0.449**	0.463**	0.369**	0.459**	0.510**	0.603**
P x S	3	0.002	0.011	0.004	0.004	0.003	0.006	0.005
V x S	3	0.055*	0.047**	0.093**	0.080**	0.094**	0.082**	0.061**
P x V x S	3	0.005	0.002	0.006	0.005	0.002	0.006	0.002
Error (b)	24	0.004	0.007	0.003	0.002	0.002	0.001	0.001