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Yield and Nutrients Profile of Potato Tubers at Various Stages of Development

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Abstract: The experiment was conducted to investigate the yield and nutrient losses and economic return at various stages of harvest in potato crop. Plant height and plant spread increased from 31.8 and 41.58 at HD60 to 40.3 and 50.58 cm at HD90. The number of stems per plant also increased from 3.55 at HD60 to 6.45 when the crop was harvested at HD90. Specific gravity and dry matter content also increased when harvesting was delayed to the optimum time. Specific gravity and dry matter contents increased from 1.075 and 19.60% at HD60 to 1.083 and 21.31% at HD90, respectively. The starch content increased gradually from 14.79% at HD60 to 15.65% at HD90 while total sugars decreased with an increase in developmental stage. It decreased from 707.75 mg/100g at HD60 to 549.50 mg/100g at HD90. Early harvested crop resulted in smaller tuber size (39.20 mm) and low yield (7.79 t ha^{-1}) at HD60 which increased to a tuber size of 64.1 mm, yielding 11.45 t ha^{-1} at HD90. The highest gross benefit (Rs. 60,810 ha^{-1}) was obtained at HD60 (Rs. 60810), which decreased to Rs. 53,940 ha^{-1} at HD90. These results suggested that although early harvest gave poor quality tubers and low yield but the market demand at this stage is high and the growers get higher return from early harvesting.

Key words: Potato, development, nutrients

Introduction

Potato is an important vegetable crop of Pakistan. Generally three crops are grown in Pakistan viz. spring, summer and autumn. The area and production of potato is consistently increasing (Anonymous, 2001). Despite, ever-increasing productivity and production, the price fluctuation through out the year is very high. Retail price may be as low as Rs. 3 kg^{-1} at the peak production season and as high as Rs. 15 kg^{-1} during the limited supply season (Malik, 1995). In the absence of adequate storage facilities, the growers tend to modify the harvest season to avoid market gluts and subsequent low prices. In Pakistan, there is an increasing tendency of harvesting potatoes before its full maturity to catch higher prices in the markets. Potato processors are mainly concerned with the colour and yield of processed products. The most important factor affecting the colour of fried processed products such as chips and French fries is the content of reducing sugars (Rao *et al.*, 1990), while the yield recovery of the processed products is directly related to the tuber yield and high specific gravity or dry matter content of tubers (Santerre *et al.*, 1986). It is advantageous to harvest the crop at full maturity, because, at this stage the tubers have the highest dry matter and protein contents and the lowest reducing sugars and free amino acid contents (Misra *et al.*, 1993). Early harvesting of potato crop may give some economic benefit to the farmers but on the other hand it affect both the yield and quality of the produce, which ultimately reduces its market/consumer value. The present study was, therefore, initiated to investigate the yield and nutrient losses of potato crop due to early harvesting in comparison to the economic return associated with early harvest.

Materials and Methods

The research studies were conducted at Horticultural Research Farm, NWFP Agricultural University Peshawar in the autumn season (1999-2000). Seed tubers (40-50 g) of potato cv. Cardinal were planted in the plots (3x4 m^2) keeping the distance between rows and seed potatoes were 75 and 20 cm respectively. The plots were arranged in randomized complete block design (RCBD) with four treatments of different harvesting stages. Harvestings were done at 60, 70, 80 and 90 days after sowing (Harvesting Day=HD60, 70, 80 and 90 respectively) and data on vegetative growth (plant height, plant spread and number of stems per plant), quality attributes (specific gravity, dry matter, starch content and total sugars) and yield attributes e.g. tuber size, yield and economic return were recorded at each harvest stage.

Specific gravity of tubers was determined by the weigh-in-air/weigh-in-water method. Representative samples of freshly harvested tubers were collected on each date and analyzed for starch and total sugar. Starch content was determined by direct acid hydrolysis (Anonymous, 1965). Total sugar was determined by the acid hydrolysis and Lane Eynon method as reported by Khalil and Manan (1990).

Tuber size was recorded with vernier caliper. Yield ha^{-1} was approximated from yield/plot and economic return

was estimated by surveying 10 wholesale retailers at the harvest day (HD 60. 70, 80 and 90).

Results and Discussion

Vegetative growth: Vegetative growth is an important factor that determine the ultimate plant production. In many annual crops vegetative growth ceases or slow down at the onset of reproductive activity (flowering or tuberization). The highest values for plant height, plant spread and number of stems per plant were observed at HD90 but these were nonsignificantly different from HD80 (Table 1). It indicate that vegetative growth in potato slows down after reproductive structures (tubers or flowers) are initiated (Malik, 1995). The extent of vegetative growth achieved by HD80 was 97.47 and 96.18% for plant height and spread respectively. The increase in number of stem per plant was, however, nonsignificant after HD70 and 84.5% of the maximum number of stems was at HD70. It indicates that the maximum vegetative growth was achieved by HD80 and after that there is very little increase in vegetative growth of potato (Table 1). Decreased rates of vegetative growth at this stage can be expected because more assimilates were partitioned toward the reproductive parts e.g. tubers (Khan *et al.*, 1990).

Specific gravity and dry matter: The specific gravity and dry matter of the potato were determined at each harvest stage. The data showed that both specific gravity and dry matter varied significantly among different harvest stages. Specific gravity and dry matter were higher with increased time to harvest. The highest specific gravity was recorded at HD90 (1.083), followed by 1.081 at HD80 with the difference being nonsignificant. HD70 and 60 resulted in significantly lower specific gravity (1.079 and 1.075 respectively). Dry matter of the tubers was highest in HD90 (21.31%) followed by nonsignificanly lower value (20.97%) in HD80. The dry matter content on the average basis at HD80, 70 and 60 was significantly lower (20.53 and 19.60% respectively) (Table 2). Specific gravity and dry matter content of the tubers are important quality attributes in potato. The highest dry matter content of 21.31 with the highest specific gravity of 1.083 was recorded in samples of HD90 plots and significantly lower value of specific gravity (1.075) with lower in specific gravity and dry matter content was numerically higher but nonsignificant between HD70 and HD80 and HD80 and Hd90. However it was significantly higher in HD90 as compared to HD70 (Table 2). It is clear that the both dry matter content and specific gravity increase at a slower rate after DH70, indicating that while growth continue, maturation is also initiated at this stage. These results can also be attributed to the fact that initially tuber growth is accomplished more by cell elongation with relatively low dry matter accumulation, which may begin after the cessation of vegetative growth (Marwaha, 1998).

Starch content (%): The results showed that like other parameters starch content also varied significantly with developmental stages. It was higher when the crop harvest was delayed to HD90. The highest starch content was recorded at HD90 (15.65%) fallowed by HD80 with a starch content of 15.47%. The starch content at both harvest stages, however, was nonsignificantly different. When the crop is harvested at HD70 and 60, the starch content decreased significantly with incremental decrease in harvest time so that at HD 60 it decreased to 14.79% (Table 2). Since potato tubers are storage organs, the results indicated a reasonable trend of starch accumulation as harvesting is delayed from HD 60 to HD90 (Table 1). The starch content of 14.79% at HD60 gradually increased to 15.27, 15.47 and 15.65% at HD70, 80 and 90 respectively. However, the difference in starch content between HD80 and 90 was non-significant, indicating that the rate of starch accumulation is decreased after HD80. This can happen if the tubers are approaching internal maturity. Since starch is a storage form of carbohydrates, its accumulation is generally initiated once the growth phase is more or less complete (Marwaha, 1998). These results, however, do not agree with the findings of Torres (1980) who reported that starch and dry matter contents decreased from HD85 onward.

Total sugar (mg/100g): Total sugars in mg per 100 g of potato were determined at each harvest stage. It is evident from the result that the total sugar was higher at early harvest stages as compared to delaying harvest to the optimum stage of tuber maturity (Table 1). The highest value of total sugar was observed at HD60 (707.75 mg/100g), which decreased significantly to 620.25 mg/100g when the crop is harvested at HD70. Further extension in harvest stage to HD80 and 90 caused significant decrease in total sugars to 591.50 and 549.50 mg/100g, respectively. Total sugars represented a trend that was the reverse of starch content. Different harvest stages significantly affected the total sugar content of potato tuber. Unlike starch, it was higher at shorter period of harvest, which gradually decreased with increase in time given to the crop in the field. Since the free sugars were converted to starch as the tubers approached maturity, it is expected that it will be decreased further with increase in harvesting dates (Jewell and Stanley, 1989; Marrwaha, 1998; Singh *et al.*, 1999). Thus it is clear that early harvested potato have not only low starch but high sugar content which is negatively correlated with chip colour and tuber edible quality (Sinha *et al.*, 1992).

Table 1: Plant height, spread and number of stems per plant for various harvest stages

Harvest stages	Plant height (cm)	Plant spread (cm)	Stems/plant
HD60	31.55b	41.58b	3.55c
HD70	34.30b	45.00a	4.45b
HD80	39.28a	48.65a	6.00a
HD90	40.30a	50.58a	6.45a
LSD at 5%	5.043	4.652	1.364

Table 2: Specific gravity, dry matter, starch content and total sugar (mg/100g fresh wt) at various harvest stages

Harvest stages	Specific gravity	Dry matter content (%)	Starch content (%)	Total sugar (mg/100g)
HD60	1.075c	19.60c	14.79c	707.75a
HD70	1.079b	20.53b	15.27b	620.25b
HD80	1.081ab	20.97ab	15.47ab	591.50bc
HD90	1.083a	21.31a	15.65a	549.50c
LSD at 5%	0.003	0.638	0.245	65.131

Means followed by different letters are significant at 5%.

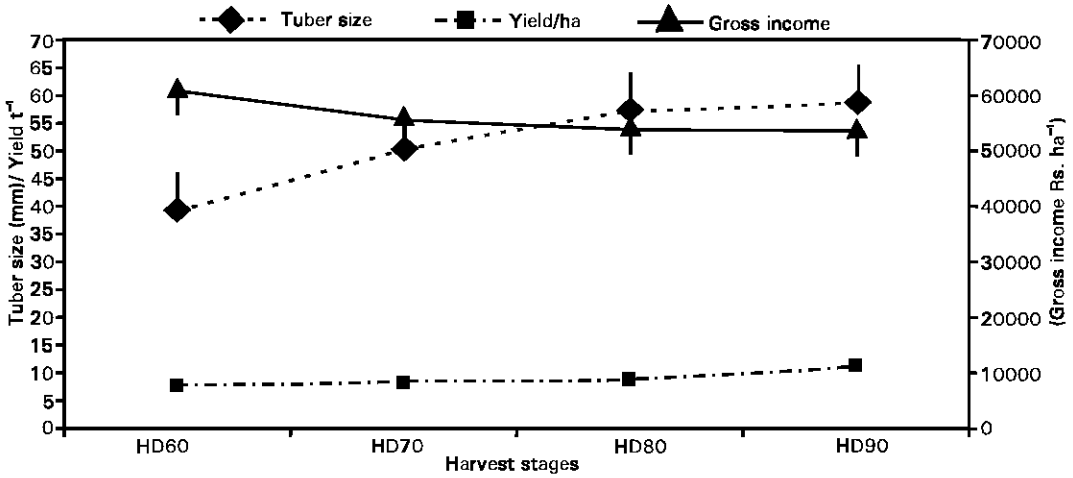

Fig. 1: Tuber size, yield t ha^{-1} and gross income of potato harvested at different stages of maturity

Tuber size (mm): The results indicate the size of the tuber increased significantly with incremental increase in harvest time (Fig. 1). At the earliest harvest (HD60) the average tuber size was 39.2 mm at HD 60 which significantly increased to 50.55 mm at HD70. Further delay in harvesting time caused additional increase in size of the tubers, so that it was 57.2 and 64.1 mm for HD80 and 90 respectively. Since the tubers are initiated even before HD60, tuber size of potato was significantly affected by time of harvest. The size of the tuber was more when longer period was allowed for growth and development as compared to early harvest. These results indicated that the tubers were initiated even before 60 days of planting and some development (61.15% of DH90) has taken place by DH60, major growth and development is accomplished somewhere after 70 days of planting when vegetative growth was minimum. The size increase accumulation during last 20 days (DH70 to DH90) was 13.55 mm, resulting in average tuber size of 64.1 mm by HD90 (Martin, 1992).

Yield (tons ha^{-1}): The yield data (Fig. 1) reveals significant increase with extension in harvest stages the lowest yield of 7.79 t ha^{-1} in this experiment was recorded in HD60. The yield increased to 8.50 and 8.98 t ha^{-1} when the crop was harvested at HD 70 and 80. Another 10 days delay in harvesting resulted in significant increase in the yield 11.45 t ha^{-1}.

Different harvesting stages significantly affected the yield (t ha^{-1}). There was an incremental increase in yield (t ha^{-1}) when the crop was allowed in the field for longer period. Results showed that yield (t ha^{-1}) at HD 90 was significantly more than the yield obtained at HD60, 70 and 80. Higher yields (t ha^{-1}) at HD80 and 90 were in agreement to our conclusion that vegetative growth ceases after HD80 and the photosynthates formed afterwards, were preferentially partitioned to tuber developments. Since at HD60 and 70 both vegetative

growth and tuber development take place simultaneously, which resulted in poor tuber yield (Marwaha, 1998). Some researcher have found that tuber size and yield may further increase even after HD90 (Martin, 1992; Plooy *et al.,* 1988; Stanley, 1990). But environmental stresses such as frost limit further growth of the tubers and increase in yield (Ahmad, 1988; Khan *et al.,* 1990).

Gross income (Rs. ha^{-1}): The gross income was calculated at each harvest stage by taking average wholesale prices of potatoes at the time of each harvest. The results showed that gross income values of potato varied significantly with different dates of harvest. Highest gross benefit of Rs. 60810 ha^{-1} was obtained from early harvesting (HD60) which was significantly higher than the rest of three harvest stages. The gross income at HD70 was Rs. 55910 ha^{-1}. There was a numerical decrease in gross benefit with delaying harvest so that at HD90 the it was down to Rs. 53940 ha^{-1}. The differences in HD70, 80 and 90, however, were nonsignificant. It is evident from Fig. 1 that the income from potato is less a function of yield than the market situation at the time of harvest. The prices of potato in the market are mainly associated with supply and demand. Whereas higher yield can be indicator of good return but when accompanied by high demand. The maximum gross benefit was obtained with low yield of HD60. Because at this stage the supply of potatoes to the markets is low, while the demand is high. Although, the yield increased significantly by delaying harvest, the gross return from HD70, 80 and 90 was nonsignificant. The increase in yield from 7.79 at HD60 to 11.45 could not compensate for the economic return, which actually decreased by Rs. 6870. Similar low increase in yield at later harvest stages, which is not sufficient to overcome effect of low market prices was also reported by Khan *et al.* (1990) and constitute a serious problem of potato marketing system in Pakistan.

It is clear from this study that early harvesting of potato causes poor nutritional value and quality but since it captures good price in the market. This situation, undesirable though, may continue if supply of potato is not limited in the market at the early stages of harvest.

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