# DRY MATTER ACCUMULATION IN POTATO CLONES UNDER SEASONAL HIGH TEMPERATURE CONDITIONS IN PAKISTAN[1]

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**Abstract**

The effects of seasonal high temperatures on potatoes were investigated under field conditions near Peshawar, Pakistan. Five potato clones (A79196-1, Desiree, DTO-28, LT-1, Russet Burbank) were grown during the spring season at two locations. Canopy development, vine dry weight and tuber dry weight were determined at 13-day intervals, starting 68 days after planting (DAP). Tuber yield was higher in heat tolerant clones compared to heat susceptible clones. Location significantly affected tuber dry weights. Tuber dry weights of Russet Burbank were consistently lower than those of DTO-28. Ground canopy cover of DTO-28 occurred earlier and reached maximum at 75 DAP, compared to 90 DAP for Desiree. DTO-28, because of its high tuber yield under cool as well as hot temperatures, and its relatively early bulking, should be a promising clone for a short duration crop in hotter regions.

**Compendio**

Se investigó el efecto de las altas temperaturas de estación sobre plantas de papa en condiciones de campo, cerca de Peshawar, Pakistan. Durante la estación primaveral se sembraron cinco clones de papa (A79196-1, Desiree, DTO-28, LT-1, Russet Burbank) en dos localidades. Se determinó el desarrollo del follaje, el peso seco de las ramas y de los tubérculos, a intervalos de 13 días a partir de los 68 días después de la siembra (DAP). El rendimiento fue más alto en clones tolerantes al calor que en clones susceptibles al calor. La localidad afectó en forma significativa al peso seco de los tubérculos. El peso seco de los tubérculos de Russet Burbank fue menor, de manera consistente, que el de los tubérculos de DTO-28. El follaje cubrió

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el campo más temprano en el clon DTO-28, alcanzando su punto máximo a los 75 DAP, comparado con 90 días para Desiree. El clon DTO-28 puede ser promisorio para cultivos de corta duración en regiones mas cálidas, debido a su alto rendimiento en condiciones tanto frías como calientes y a su desarrollo relativamente precoz.

## Introduction

Heat stress is a major factor limiting potato production in Pakistan during the spring crop. Air temperatures are too low for optimum growth until the end of February (10 C ave.) and then rise to excessively high levels at the end of April (28 C ave.), allowing only a short period for optimum growth and development. Low soil temperatures cause early tuber initiation (8), slow vine growth, and small leaf area, which result in low light interception. High temperatures cause profuse vine growth (16), low photosynthesis (2, 7), high respiration (22), and low dry matter partitioning to the tubers (9). Winkler (22) reports that 17 C was the optimum temperature for tuber dry matter production of three potato cultivars. Maximum shoot growth occurs at temperatures of 22 to 30 C (1), and maximum tuber growth occurs at 15 to 30 C (8). Continuous high temperatures have more severe effects on potato production than fluctuating day and night temperatures (9). Low night (12 to 15 C) temperatures favor tuber production (18, 19).

Genetic variability for heat tolerance in potato clones has been reported by Dwelle (7), Khedher and Ewing (12), and Mendoza and Estrada (17). The availability of heat tolerant germplasm from the International Potato Center at Lima, Peru, and from other agencies opens opportunities for further work on heat stress tolerance and possible selection of new cultivars suitable for regions like Pakistan. The present study was conducted near Peshawar, Pakistan, to investigate the effects of high temperature on dry matter accumulation during different phases of crop growth in three heat tolerant and two heat susceptible clones.

## Materials and Methods

This study included five potato clones; DTO-28, LT-1, and Desiree as heat tolerant, Russet Burbank and A79196-1 as heat susceptible. Classification as heat tolerant or susceptible was based on reports of greenhouse and field trials (12, 20).

Field experiments were conducted near Peshawar, Pakistan (34 N latitude and 360 m asl.), at two different locations 30 kilometers apart with similar climatic but different soil conditions. Experiment 1 was carried out at the Agriculture Research Institute Tarnab (Tarnab Farm), and Experiment 2 was carried out at the Research Farm of the North West Frontier Province Agricultural University (University Farm).

At Tarnab Farm, the previous crop was turnip followed by 4 months of fallow. The soil at Tarnab Farm was a silty loam with pH 7.5 and 1.5% organic matter. The land at University Farm was fallow for the preceding 14 months. The soil was clay loam, with a pH of 7.7, and organic matter less than 1%. Both sites were gravity irrigated.

Prior to planting, 75 kg $ha^{-1}$ of N (ammonium nitrate), 50 kg $ha^{-1}$ P (super phosphate), and 150 kg $ha^{-1}$ K (potassium sulfate) were applied broadcast and incorporated into the soil. The same quantity of fertilizer was incorporated 40 days after planting by broadcasting and hilling into the ridges.

Seed was imported from the USDA potato breeding program at Aberdeen, Idaho. Seed potatoes were harvested in October 1987, and were air-shipped to Peshawar. The seed was stored at room temperature (15 to 20 C) until planting at the Tarnab Farm on February 3, and at the University Farm on February 5, 1988. Seventy-two hours prior to planting, seed tubers were cut into pieces of 60 to 70 g each, treated with Mancozeb fungicide dust and then allowed to suberize. Seed pieces were planted on flat ground at a distance of 0.8 m between rows and 0.25 m within rows. Ridges were made by covering the seed pieces with soil. Each test clone was planted in two-row plots, and between each test clone two rows of cv. Cardinal were planted to reduce interaction that might exist between the test clones. Each row was 5 m long containing 15 plants of test clones and 5 plants of cv. Cardinal on both ends of the row to reduce border effects. Treatments were replicated 4 times in a split plot design where clones were assigned as main plots and harvest dates as subplots.

Soil moisture levels were maintained at 60 to 70% available soil moisture (monitored by the feel method) to avoid drought stress. Irrigation intervals were generally 3 to 7 days. Several precautionary sprays of Mancozeb fungicide were applied for the control of early and late blight. No sign of these diseases was observed on the crop.

Emergence data were recorded twice weekly until 80% of the total plants had emerged. Ground cover by crop canopy was recorded as described by Burstall and Harris (3), using a 1.0 × 0.8 meter grid with 100 squares. One set of plants per clone was measured every two weeks throughout the growing season. Beginning 68 days after planting (DAP), four plants of each clone from each replication were harvested at 13-day intervals for a total of five harvest dates. In the last harvest, only tuber weights were recorded because of early vine death in some clones. The plant parts were oven dried, first at 102 C for 8 hours and then at 70 C for 3 to 4 days.

Daily air and soil temperatures were recorded at the meteorological station in a field at Tarnab Farm (50 m from the experiment site). Soil temperatures in the plots were recorded twice weekly, at a depth of 15 cm within the ridge. Soil temperature measurements were taken between 8 to 9 am and then again at 2 pm.

Data were statistically analyzed using a general linear model, and Fisher's Protected Least Significant Difference procedure was used for comparison of the treatment means.

## Results

*Temperatures*—The weekly mean minimum air temperatures ranged from 5 to 23 C, and weekly mean maximum temperatures ranged from 22 to 41 C (Figure 1). Soil temperatures at 15 cm depth were between 10 to 22 C. The monthly means for air temperatures were: February, 13.6 C; March, 16.3 C; April, 21.7 C; and May, 25.2 C. Temperature records for

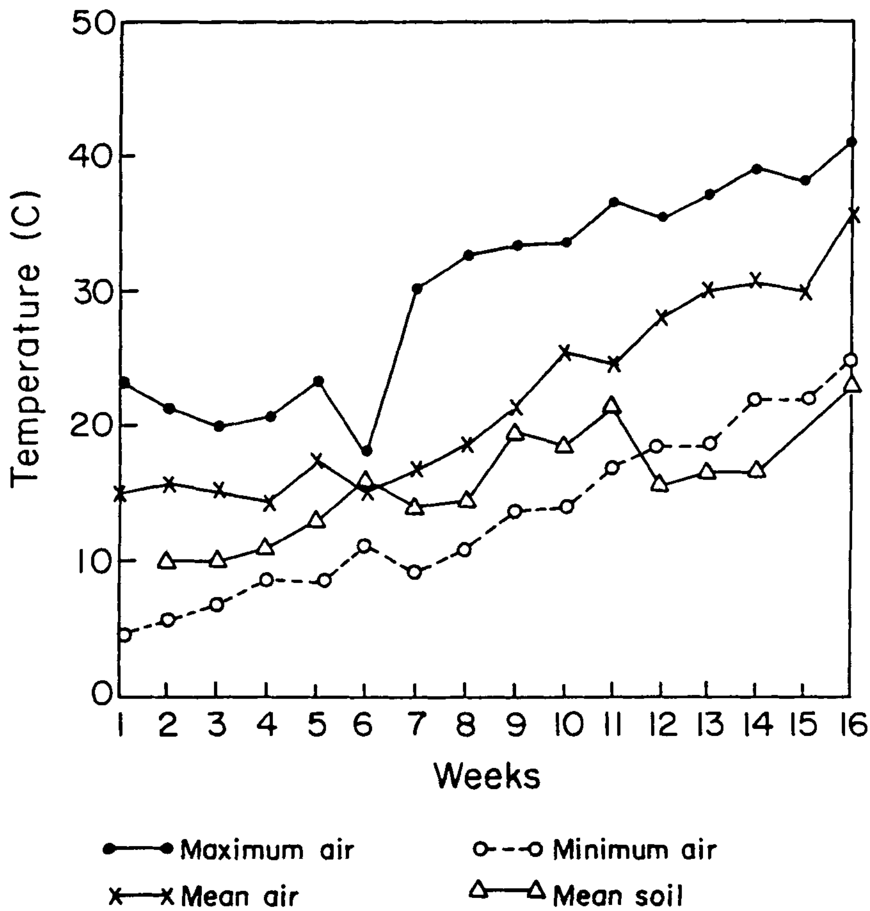


FIG. 1. Daily maximum and minimum air temperatures, and mean air and soil temperatures (at the depth of 15 cm) in experiment conducted near Peshawar, Pakistan, during spring crop season, February - May, 1988.

the Peshawar region indicate monthly mean air temperatures as follows: February 11.4 C; March, 16.3 C; April, 21.5 C; and May, 27.5 C (11).

*Emergence*—Low temperatures in February resulted in slow emergence of all clones, especially that of Russet Burbank (Table 1). The emergence was slower at the University Farm compared to Tarnab Farm. At the University Farm only DTO-28 reached greater than 50% emergence by 30 DAP. At that time, DTO-28 had higher emergence percentage compared to A79196-1, Desiree, and Russet Burbank at the Tarnab Farm and had the highest emergence percentage at the University Farm compared to the other clones. Russet Burbank had the slowest emergence at both locations compared to the other clones. By March 21 (49 DAP and 52 DAP for the Tarnab Farm and the University Farm, respectively) emergence of all clones was 80% or higher at both locations.

*Canopy Development*—Canopy development at the University Farm was earlier than at the Tarnab Farm. However, later in the season, the percent soil coverage for plants grown at the Tarnab Farm was higher than that of those grown at the University Farm (Figure 2). At the Tarnab Farm, soil coverage was more than 80% for DTO-28 at about 75 DAP and reached 80% for Desiree, Russet Burbank and LT-1 at about 90 DAP. Desiree, DTO-28 and A79196-1 exhibited maximum percentage soil coverage between 90 and 104 DAP. Percentage soil coverage declined rapidly after that time at both locations. In contrast, Russet Burbank and LT-1 had slower canopy development than other clones, but also had later senescence.

*Vine Dry Weight*—At 68 DAP, vine dry matter accumulation was higher for DTO-28 at the Tarnab Farm compared to the other clones and at University Farm compared to A79196-1 and Russet Burbank (Table 2). AT 107 DAP, vine dry matter were maximum in all clones at both locations, except for A79196-1 at the University Farm which reached maximum at 94 DAP. At the Tarnab Farm, Desiree and LT-1 had significantly higher vine dry

TABLE 1.—*Percent emergence of five potato clones 30 days after planting in two experiments conducted near Peshawar, Pakistan, during spring season, February to May, 1988.*

| | Precent Emergence | |
|---|---|---|
| Clone | Tarnab Farm | University Farm |
| A79196-1 | 52.5[x] | 20.0 |
| DTO-28 | 78.3 | 65.8 |
| Desiree | 54.1 | 22.5 |
| LT-1 | 65.8 | 15.8 |
| Russet Burbank | *24.1* | *5.0* |
| LSD 5% | 19.6 | 18.0 |

[x]Values are means of four replications.

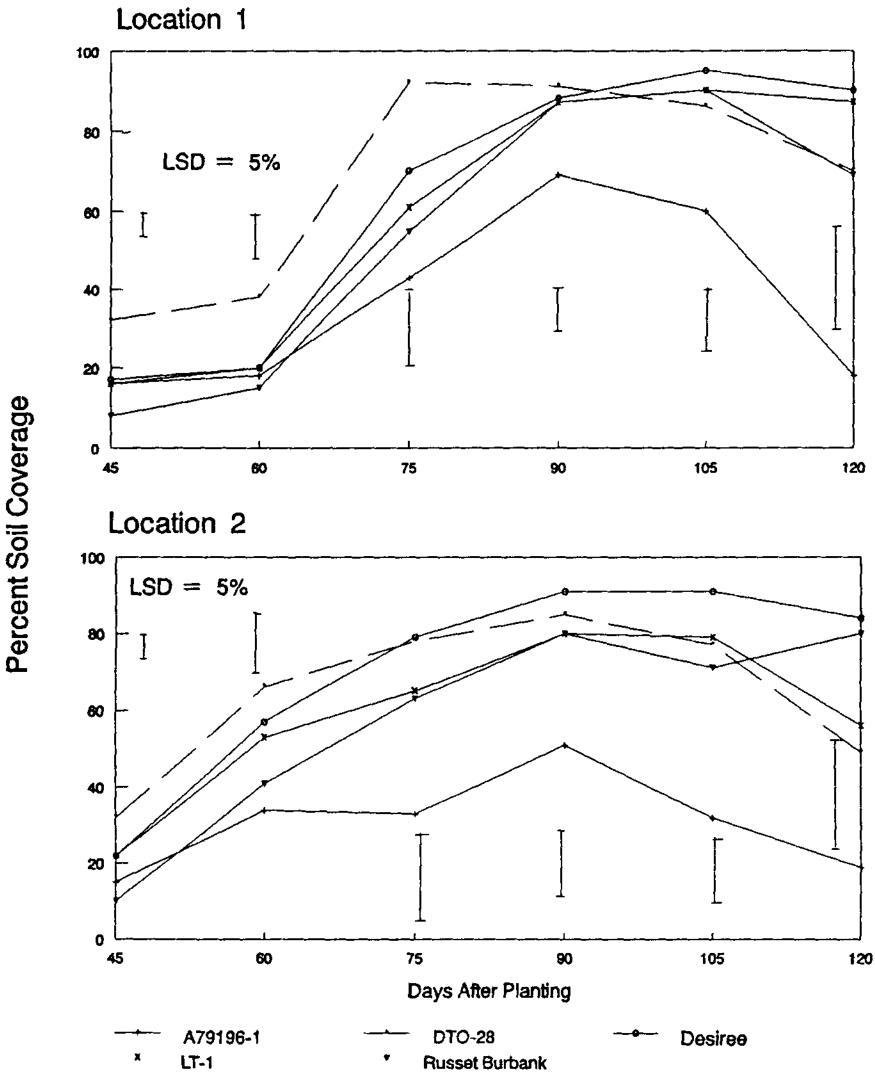


FIG. 2. Canopy development by five potato clones under high seasonal temperatures at two locations near Peshawar, Pakistan, during spring crop season, February - May, 1988. (Location 1 - Tarnab Farm; Location 2 - University Farm.)

matter at 107 DAP compared to A79196-1. At the University Farm, Desiree had the highest and A79196-1 had the lowest vine dry matter compared to the other clones.

*Tuber Dry Weight*—Clones had maximum tuber dry matter at 107 DAP, except A79196-1 and Desiree at the University Farm (Table 2). A79196-1

TABLE 2.—*Vine and tuber dry matter of five potato clones grown during February to May, 1988 in Peshawar, Pakistan, and harvested at five dates after planting.*

| | Tarnab Farm | | | | | University Farm | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Days After Planting** | | | | | | | | | |
| Clones | *68* | *81* | *94* | *107* | *120* | *68* | *81* | *94* | *107* | *120* |
| | Vine dry weight (g $m^{-2}$)[y] | | | | | | | | | |
| A79196-1 | 106 | 114 | 112 | 176 | - | 59 | 79 | 86 | 79 | - |
| DTO-28 | 204 | 227 | 232 | 236 | - | 109 | 168 | 175 | 210 | - |
| Desiree | 119 | 221 | 271 | 324 | - | 100 | 268 | 271 | 330 | - |
| LT-1 | 135 | 170 | 294 | 344 | - | 83 | 135 | 185 | 202 | - |
| Russet Burbank | *117* | *163* | *225* | *281* | - | *59* | *174* | *240* | *243* | - |
| LSD 5% | 44 | 76 | 76 | 140 | - | 26 | 114 | 70 | 61 | - |
| | Tuber dry weight (g $m^{-2}$)[y] | | | | | | | | | |
| A79196-1 | 196 | 268 | 309 | 402 | 296 | 89 | 166 | 171 | 249 | 262 |
| DTO-28 | 145 | 399 | 426 | 464 | 414 | 82 | 202 | 220 | 354 | 324 |
| Desiree | 136 | 239 | 346 | 390 | 365 | 121 | 159 | 189 | 192 | 252 |
| LT-1 | 120 | 250 | 344 | 485 | 280 | 98 | 170 | 207 | 310 | 296 |
| Russet Burbank | *80* | *168* | *285* | *323* | *270* | *48* | *79* | *167* | *167* | *162* |
| LSD 5% | 71 | 130 | NS[z] | NS | 76 | 40 | 60 | NS | 96 | 155 |

[y]Values are means of four replications.
[z]NS = Nonsignificant at 5%.

and Desiree had the maximum tuber dry matter 120 DAP at the University Farm. At 81 DAP, DTO-28 had significantly higher tuber dry matter compared to other clones at the Tarnab Farm; however, at the University Farm its tuber dry matter was only higher than Russet Burbank. At 120 DAP, DTO-28 had significantly higher tuber dry matter at the Tarnab Farm compared to A79196-1, LT-1 and Russet Burbank.

## Discussion

Sale (21) showed that the days to 50% emergence for potatoes depended upon the mean daily temperature, with fastest emergence at about 22 C. Epstein (8) reported that soil temperatures of 16 to 22 C were optimum for emergence. The soil temperatures in our study were below 15 C for most of the first 6 weeks (Figure 1). Because of the low soil temperatures, emergence was greatly delayed at both locations. Delaying planting until soil temperatures are higher seems a suitable option for better emergence in the spring. However, the usual rains in the last half of February often makes later planting difficult.

Experiment locations had significant effects on emergence rates, as well as dry weight of vines and tubers (Table 1 & 2). Inferior performance of clones at the University Farm may have been due to several factors, such as soil structure and fertility, soil crusting during emergence and later planting date. Manrique (15) reported that soil structure of the surface layer was an important factor for emergence in Hawaiian conditions, and higher soil resistance reduced percent emergence of potato cultivars. Late emergence of Russet Burbank was due to its long dormancy period which in turn affected its productivity.

Tuber dry weights increased greatly between 68 DAP and 81 DAP, peaked at 107 DAP (except for A79196-1 and Desiree at the University Farm), and then declined at 120 DAP (Table 2). The loss of dry matter from the tubers at 120 DAP was not expected. However, these results agree with those of Bodlaender (2). He reported a similar decrease in tuber yield and total dry weights late in the season in the Netherlands, and attributed this decrease to regrowth of sprouts from tubers, and high respiration rates. This is in direct contrast to what typically occurs under Idaho field conditions late in the season. There the temperatures are cooler and tuber dry matter increases until crop maturity (5, 12). In our study the reduction in dry weight may have been due to: 1) high respiratory losses in tubers (4), and 2) remobilization of carbon assimilates from tubers to the vines due to the high temperatures. Gawronska and Dwelle (10) reported that under environmental conditions that limit net carbon assimilation, vines can become the dominant sinks for assimilates. The mean air temperatures between 107-120 DAP were 30-35 C.

Heat tolerant clones tended to perform better than heat sensitive clones. The excellent early yield of DTO-28 at 81 DAP (9.6 t/ha tuber fresh weight at Tarnab Farm, data not shown), and its general yielding ability under cool as well as hot conditions (6, 12) make this clone suitable for early harvest in areas where crop growth duration is short (14). LT-1, conversely is a later maturing clone and its performance was comparable to Desiree. Heat sensitive clones (Russet Burbank and A79196-1) produced relatively low tuber yields at both locations. Lower dry matter yield by Russet Burbank compared to the other clones may have been due to its long dormancy and later emergence.

The potato clones exhibited two distinct plant growth types. Desiree, DTO-28 and A79196-1 had determinant type growth under the environmental conditions of this experiment, while Russet Burbank and LT-1 had indeterminate growth. A79196-1 is a determinate type and seems to have a tendency for very early tuber initiation under cool temperature conditions. Determinant types are characterized by small, bush type foliage growth and early to mid-season maturity (13). Indeterminate types are characterized by large, vine type foliage growth, and mid- to late-season maturity. Early canopy development, early tuber initiation and faster bulking rates are essential factors for high productivity in the spring crop when crop duration is short. This indicates that conditions during the spring crop in Pakistan are favorable for potato clones with determinant type growth habit.

Breeding early tuber initiation (A79196-1) with early canopy development (DTO-28) may result in a high yielding clone for the spring crop of Pakistan. Further investigation of the clones studied in these experiments is needed under autumn conditions of Pakistan to establish their performance under complete growth cycles.

### Literature Cited


1. Benoit, G.R., C.D. Stanley, W.J. Grant and D.B. Torrey. 1983. Potato top growth as influenced by temperatures. Am Potato J 60:489-501.
2. Bodlaender, K.B.A. 1978. Photosynthesis, respiration, and dry matter production of potatoes. (EAPR report). Potato Res 21:40.
3. Burstall, L. and P.M. Harris. 1983. The estimation of percent light interception from leaf area index and plant ground cover in potato. J Agron Sci 100:241-244.
4. Burton, W.G. 1978. The physics and physiology of storage. *In:* The Potato Crop. P.M. Harris (Ed.). John Wiley & Sons, New York, pp. 545-601.
5. Dawes, D.S., R.B. Dwelle, G.E. Kleinkopf and R.K. Steinhorst. 1983. Comparative growth analysis of Russet Burbank potatoes at two Idaho locations. Am Potato J 60:717-733.
6. Demagante, A.L. and P. Vander Zaag. 1988. The response of potato (*Solanum* spp.) to photoperiod and light intensity under high temperatures. Potato Res 31:73-83.
7. Dwelle, R.B. 1985. Photosynthesis and photoassimilate partitioning. *In:* Potato Physiology P.H.Li (Ed.). Academic Press, Inc., NY. pp. 35-58.
8. Epstein, E. 1066. Effects of soil temperatures at different growth stages on growth and development of potato plant. Agron J 58:169-172.
9. Ewing, E.E. 1981. Heat stress and the tuberization stimulus. Am Potato J 58:31-49.
10. Gawronska, H. and R.B. Dwelle. 1989. Partitioning of photoassimilates by potato plants (*Solanum tuberosum* L.) as influenced by irradiance. I. Partitioning patterns in Russet Burbank grown under high and low irradiance. Am Potato J 66:201-213.
11. Gohan, A. and N. Rahman. 1990. Meteorological observations at Tarnas, Peshawar. Directorate of soil and plant nutrition, Agric Res Inst, Tarnas, Peshawar, Pakistan. p. 21.
12. Khedher, M.B. and E.E. Ewing. 1985. Growth analysis of eleven potato cultivars grown in the greenhouse under long photoperiod with and without heat stress. Am Potato J 62:537-554.
13. Kleinkopf, G.E., D.T. Westermann and R.B. Dwelle. 1981. Dry matter production and nitrogen utilization by six potato cultivars. Agron J 73:799-802.
14. Levy, D. 1986. Tuber yield and tuber quality of several potato cultivars as affected by seasonal high temperatures and by water deficit in a semi-arid environment. Potato Res 29:95-107.
15. Manrique, L.A. 1989. Analysis of growth of Kennebec potatoes grown under different environments in the tropics. Am Potato J 66:277-291.
16. Marinus, J. and K.B.A. Bodlaender. 1975. Response of some potato varieties to temperature. Potato Res 18:189-204.
17. Mendoza, H.A. and R.N. Estrada. 1979. Breeding potatoes for tolerance to stress: heat and frost. *In:* Stress Physiology in Crop Plants. H. Mussell and R.C. Staples (Eds.), John Wiley and Sons, New York. pp. 228-262.

18. Milthorpe, F.L. and J. Moorby. 1966. The growth of the potato. Proc 3rd Trien Conf EAPR. pp. 51-70.

19. Moreno, U. 1985. Environmental effects on growth and development of potato. *In:* Potato Physiology. P.H.Li (Ed.). Academic Press, NY. pp. 481-500.

20. Morpurgo, R. and R. Ortiz. 1988. Morphological variation of the potato (*Solanum* spp.) under contrasting environments. Env and Exp Bot 28:165-169.

21. Sale, P.J.M. 1979. Growth of potatoes (*Solanum tuberosum* L.) to the small tuber stage as related to soil temperature. Aust J Agron Res 30:65-81.

22. Winkler, E. 1971. Potato cultivation in Tyrol. II. Photosynthetic efficiency and respiration in different potato varieties. Potato Res 14:1-18.