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EFFECT OF TEMPERATURE AND WATER POTENTIAL ON SP ROUTING OF POTATO (*Solanum tuberosum* L.) SEED TUBERS FROM DIFFERENT SEED LOTS

Pengaruh Suhu dan Kelembaban terhadap Pertunasan Umbi Kentang *(Solanum tuberosum* L.*)* dari Beberapa Lot Benih

Ifayanti Ridwan[1], Phil H. Brown[2], Shaun N. Lisson[3], Nurfaida[1]
e-mail: Ifayanti@yahoo.com.au
[1]Faculty of Agriculture, Hasanuddin University, Makassar
[2]School of Horticultural Science, Central Queensland University, Australia
[3]School of Agricultural Science, University of Tasmania, Australia

ABSTRACT

A study was conducted to test the germination of several lots of potato seed tubers at different temperature and water potential. The experiment was performed in controlled growing environment using a thermo-gradient table Terratec at the School of Agricultural Science, University of Tasmania, Australia. Seed tubers (grade 45-65 g) of three different seed lots (330, 370 and 340 days after harvest) were planted at four temperature treatments (10, 15, 20 and 25 °C) and three different water potential (-0.6, - 0.4 and -0.02 MPa). Growth media used in this experiment was vermiculite (Grade 2, vermiculite Australia and Perlite Co-P / L). The water potential treatments were prepared based on the relationship of water content and water potential by Whalley et al. (2001). Two seed tubers are planted in each plastic container containing growth media at a depth of 10 cm and covered by the growing medium and sealed. Analysis of Variance and further test of Least Significant Difference (LSD) were performed using SPSS version 14.0 to determine the response of the seed lots to temperature and humidity. Temperature and soil water potential significantly affect the number of sprouts of potato tubers.No significant differences were found in the seed lot used in both the number of sprouts produced and sprout vigor expressed as sprouting capacity (fresh weight (FW) sprouts / FW tuber). Sprout vigor increased with the water potential treatments with the greatest response was observed in the highest temperature treatment. Temperature and humidity interacted significantly ($p < 0.01$) in influencing the sprout vigor of potato seed tubers that show great effect of moisture conditions at high temperatures.

Keywords : temperature, soil water potential, potato, sprouting, vigor

ABSTRAK

Sebuah penelitian dilakukan untuk menguji pertunasan beberapa lot umbi benih kentang pada suhu dan kelembaban yang berbeda. Percobaan dilakukan pada kondisi lingkungan tumbuh terkendali menggunakan meja gradient suhu (*thermo-gradient table)* Terratec pada School of Agricultural Science, University of Tasmania, Australia. Umbi benih (grade 45-65 g) dari tiga lot benih yang berbeda (330, 370 dan 340 hari setelah panen) ditanam pada perlakuan empat suhu (10, 15, 20 dan 25 °C) dan tiga potensial air (-0.6, -0.4 dan -0.02 MPa) yang berbeda. Media tumbuh yang digunakan dalam percobaan ini adalah vermikulit (Grade 2, vermiculite Australia dan Perlite Co-P / L). Penetapan potensial air dilakukan berdasarkan hubungan kadar air dan potensial air yang dikemukakan oleh Whalley et al (2001). Dua umbi benih ditanam dalam setiap wadah plastik berisi media tumbuh pada kedalaman 10 cm dan ditutupi oleh media tumbuh dan ditutup rapat. Analisis Sidik Ragam dan Uji lanjut Beda Nyata Terkecil (BNT) dilakukan dengan menggunakan SPSS versi 14.0 untuk menentukan respon dari beberapa lot umbi benih terhadap suhu dan kelembaban. Suhu dan potensial air tanah berpengaruh nyata terhadap jumlah tunas umbi kentang. Tidak terdapat perbedaan yang nyata dari lot benih yang digunakan baik dari jumlah tunas yang dihasilkan maupun dari vigor tunas yang dinyatakan sebagai kapasitas bertunas (berat basah (BB) tunas / BB umbi). Vigor tunas meningkat dengan perlakuan potensial air dengan respon terbesar terlihat pada perlakuan suhu tertinggi. Suhu dan kelembaban berinteraksi secara nyata ($p<0,01$) dalam mempengaruhi vigor tunas umbi kentang yang menunjukkan pengaruh kondisi kelembaban yang besar pada suhu tinggi.

Kata kunci : suhu, potensial air tanah, kentang, pertunasan, vigor.

INTRODUCTION

Capability of seed tubers to produce vigorous sprouts to support optimum growth and production of the crop in the next growing season is partly determined by the chronological age of the seed tubers and physiological changes in the seed tuber during storage. While the chronological age can be easily calculated, seed tuber physiological status or age is difficult to be determined up to recently. The physiological age of the seed tubers are expressed in growing and developmental phases represented by the sprouting pattern on the tuber. Thus, the physiological age of the seed tuber is the key factor influencing the sprout number and performance of the seed tubers (Struik and Wiersema 1999; Knowles *et al.* 2003; Grice 1988; Knowles and Botar 1991; Roy and Jaiswal 1997; Reust 1994 cited in Struik and Wiersema 1999; Knowles and Knowles 2006). The concept of seed tuber physiological age is that the sprouting pattern of the tubers progresses through different stages associated with the physiological status of the tuber. These stages include dormancy, which is related to very young physiological age, apical dominance, few sprouts, multiple sprouts and lastly senility or little tuber stage, which is considered as very old physiological age (Struik and Wiersema 1999). Many seed tuber management practices are aimed at controlling tuber physiological age at planting to deliver a desired stem number.

While duration and temperature of storage have been shown to have the most significant impact on seed tuber physiological age (Iritani and Thornton 1984; Jenkins *et al.* 1993; Knowles and Botar 1991), other factors such as seed crop production practices and environment (Wiersema and Booth 1985; Brown *et al.* 2003; Wurr *et al.* 2001), seed tuber size (Bohl *et al.* 1995) and damage to tubers either through impacts, pathogens or cutting of seed tubers prior to planting (Struik and Wiersema 1999; Struik *et al.* 2006) affect the rate of aging of seed tubers. Despite many reports of factors affecting the rate of tuber physiological aging, precise control of stem number through management of tuber physiological age remains an elusive goal for potato growers

The temperature and moisture conditions of the soil at planting may influence stem number. While planting environment has received little attention in the literature as a factor affecting seed tuber physiological age (Bohl 1995; Kleinkopf 2003; Pavlista 2003), the impact of temperature and water potential in the planting environment suggests either a direct involvement in the aging reactions or an interaction between planting environment and tuber physiological age in determining the sprouting pattern of the tuber after planting (Reust *et al.* 2001). Temperature, especially during storage, has been found to have an effect on physiological aging of the seed tuber (O'Brien *et al.* 1978; 1983). Data presented in Ridwan et al. (2014) revealed that temperature and moisture conditions in the planting environment affect sprout vigour, and suggested that there was an interaction between the two environment factors in their effect on the growth of sprouts originating from the seed tuber. Previous studies incorporating temperature and moisture treatments at planting have focused on crop establishment attributes such as sprout growth and time to emergence (Sale 1979; Firman *et al.* 1992). No studies have specifically investigated the possible interaction of planting environment and seed tuber physiological age on sprout number or stem number.

This research investigates the interaction between planting environment on the sprouting of the seed tubers from different lots of seed tubers that represent a range of physiological ages. The experiment reported in this article was a part of a series of trials conducted under controlled environment conditions using a thermogradient table and growth chambers to control temperature, and vermiculite media based system as documented in the previous publication (Ridwan et al. 2014) to control water potential. It was hypothesised that temperature and moisture at planting may affect the sprout number and vigour by altering the expression of the seed tuber physiological age effect.

METHODOLOGY

Growth Media and Moisture Treatment

Growth media used in this study was vermiculite (Grade 2, Australian vermiculite and Perlite Co-P / L) based on the physical properties of materials in absorbing and retaining water. Water potential treatments of -0.6, -0.4 and -0.02 MPa were utilized and set by using the relationship between water content and water potential equation (Whalley et al.2001) previously calibrated using a psychrometer (SC 10 thermocouple psychrometer Decagon Devices, Pullman, Washington) and the following calibration for water potential, Ψ, was obtained:

$$\Psi = 0.09710\theta^{-1.1223} \qquad (1)$$

where θ is the gravimetric water content.

Based on the calibration, the moisture treatments in the experiment were established by equilibrating 0.19 g, 0.36 g and 3.36 g water/g dry vermiculite for the driest (-0.6 MPa), medium (-0.4 MPa) and wettest (-0.02 MPa) moisture content, respectively. After a 24 hour equilibration period, the vermiculite for each water potential preparation was placed in plastic containers and sealed with a lid to prevent water loss from the container in order to maintain constant water potential throughout the trial.

Plant Material

Three different seed lots of cv. Russet Burbank was obtained from a seed potato research trial. The seed crop was planted on 25 November 2004 and individual seed lots were produced by varying haulm removal time to sections of the crop. Haulm removal of the seed crop for each seed lot was done at 120, 90 and 110 days after planting (DAP) for seed lots 1, 2 and 3, respectively. The seed tubers were harvested 10 days after haulm removal. For each seed lot, seed tubers were kept in 4 ºC storage after a curing period of 14 days at room temperature until the start of the experiment. At planting chronological age of the seed tubers were 330, 370 and 340 days after harvest, respectively. To avoid disease, tubers were dipped in fungicide (Rovral at 1 g L^{-1}) and dried before planting.Seed tubers were carefully handled to avoid treatments that cause stress on the tuber that can affect physiological changes.

Experimental Design and Statistical Analysis

The experiment was carried out using a Terratec thermo-gradient table at the School of Agricultural Science, University of Tasmania. The temperature treatments were set up on the thermo-gradient table by setting the temperature to 0 °C at one end of the table and 25 °C at the other end of the table. The thermo-gradient table was set up a week before the experiment was started in order to reach equilibrium. Temperature treat-ments were established by measuring the temperature at different positions on the table and setting up partitions using polystyrene material around sections of the table where the desired temperatures existed.

Seed tubers of size grade 45-65 g, sourced from three different seed lots, were exposed to four temperature (10, 15, 20 and 25 C) and three water potential (-0.6, -0.4 and -0.02 MPa) treatments. Two tubers were planted in each container at a depth of 10 cm and covered by the growth media. Containers were then re-sealed to prevent water loss. A randomized block design was employed on the thermogradient table with temperature as the block. Moisture and seed lots treatments were randomized within each temperature treatment. Two containers as replicate were used for each treatment combination, each containing 2 tubers, resulted in a total of 36 treatment combinations and 84 experimental units.

After 21 days, at the completion of each trial, sprout numbers were counted and both sprout and tuber weight recorded. Sprouting capacity was calcula-ted from the weights, and expressed as g fresh weight (FW) sprouts per g FW tuber. Using SPSS v. 14.0 (SPSS Inc. 2005) data were analysed to investigate the response of tubers to the treatments. A further test was conducted using Least Significance Difference

RESULT

Temperature and water potential had a significant impact on sprout number (Figure 1) of the seed tubers. No significant difference was found between seed lots for sprout number or for sprouting capacity. This prevented examination of possible interactions between tuber physiological age and

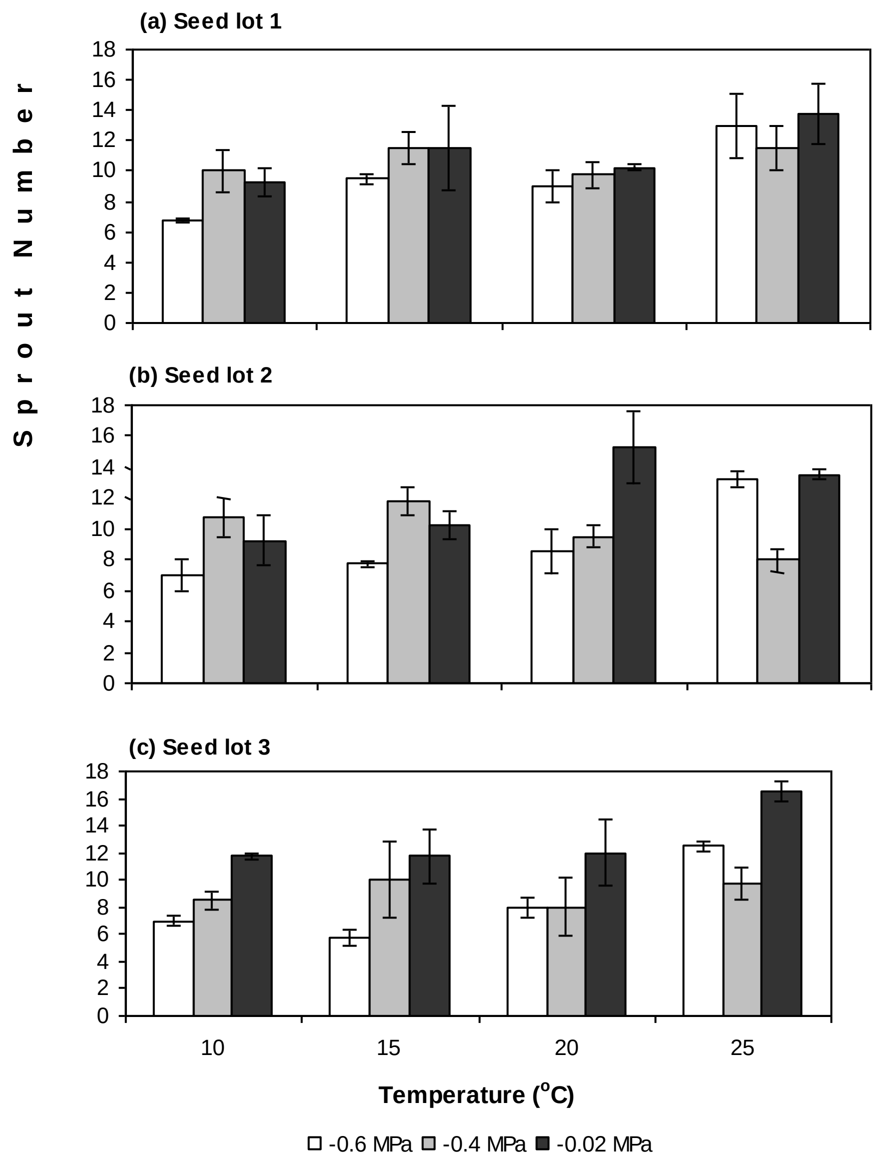

Figure 1. Sprout number of different seed lots at different temperature and water potential treatments. Tubers are exposed to temperature and water potential treatments in sealed containers for 21 days before assessment. Data are means of 4 replicate tubers. Bar corresponds to standard error of the mean.

temperature/water potential. Sprout number per tuber was very high in all seed lots, indicating that the tubers were physiologically old. Sprout number increased from a mean of 9 at 10 □C to 13 at 25 □C. The effect of temperature was greatest when water potential was lowest, with stem numbers from tubers at 10 □C approximately half that of tubers held at 25 □C in the –0.6 MPa treatment. The effect of water potential on sprout number was less than that of temperature, and was more pronounced at lower temperature than higher temperature.

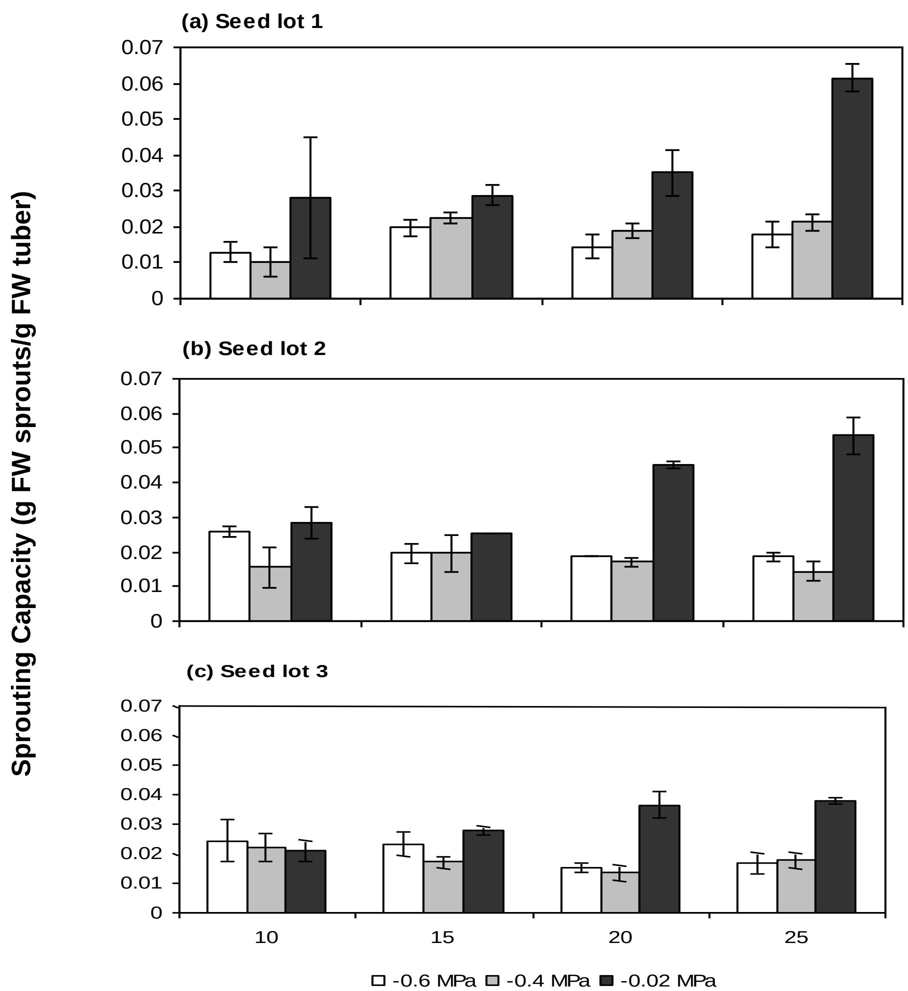

Figure 2. Sprouting capacity of sprouts of tubers from different seed lots at different temperature and moisture. Tubers are exposed to temperature and water potential treatments in sealed containers for 21 days before assessment. Data are means of 4 replicate tubers. Bar corresponds to standard error of the mean.

Sprouting capacity was found to increase in response to the increase of water potential in the growth media, with the largest response again found at the highest temperature. Temperature and water potential interacted significantly ($p<0.01$) in affecting the sprouting capacity, reflecting the higher effect of moisture conditions at higher temperature (Figure 2). In contrast to the sprout number response, no significant difference in sprouting capacity was observed between the –0.6 and –0.4 MPa water potential treatments in all temperature treatments,

DISCUSSION

This study shows that the planting environment (temperature and water potential conditions at planting) can significantly affect the number of sprouts and sprouts vigor expressed as the sprouting capacity of potato seed tubers. Absence of significant differences between the three seedlots tubers used probably due to the use of seed tubers that have been through a long storage period (330-370 days after harvest at a temperature of 4° C). Potato tubers in storage will continue to experience physiological changes and have gone through the stages of physiological aging resulted in seed tubers with older physiological age when the experiment began. Seed tubers with older physiological status usually showing no apical dominance by one or two buds indicated by more rapid shoot growth compared to other buds after the breaking of tuber dormancy period. This pattern of shoot growth generally is indicated by physiologically younger seed tubers. This is in line with that proposed by Struik (2007) that old physiological age of the seed tubers old will be indicated by the number of eye buds that bear sprouts.

However, the number and vigor of sprout per tuber of all seed lots are generally increased significantly with temperature treatment. According to Klemke and Moll (1990) temperature range of 20-25° C is optimal for sprouting shown by the presence of a two-fold increase in the number and vigor of sprouts per seed tuber at a temperature of 25° C treatment, especially at the highest water potential condition. The influence of temperature on both the number and vigor of the seed tuber sprouts has been reported in many studies. For example, for seed tubers with almost the same physiological status, number of stems per plant was higher (3.3 stems per plant) if the tubers were planted in the spring than when planted in the fall (2.2 stems per plant) on the environmental growing conditions in Tunisia (Fahem and Haverkort, 1988). This difference was attributed to the difference in the average temperature of each of 27.5° C in spring and 10° C in the fall. According Reust et al. (2001), planting environment conditions and soil temperature can affect the performance of old seed tubers in the field with low soil temperatures at planting delay the emergence and decrease the vigor of the tuber.

Variations in growing medium water potential are also shown to have effect in changing the patterns of germination of potato tubers. Lower water potential decreased the number of sprouts which in accordance with Letness (1958) who found that germination may be restricted when the seed tubers are planted in dry soil conditions. Water potential in the growing medium affects the availability of water uptake by the the potato seed tubers and the physiological status of seed tubers will determine the absorption process (Svensson 1977). Similarly, sprouting capacity or sprout vigor also decreased with the water potential treatment. Low water potential in the media likely affected the growth and development of sprouts through a decrease in cell enlargement, thereby producing smaller sprouts. These results can be compared with the responses of other plants to water shortage conditions where cell enlargement is the most sensitive to water shortages (Fitter and Hay 1989). Other researchers have reported a decline in potato stems fresh weight associated with drought treatment (Heuer and Nadler 1995).

Associated with the sprout vigor of tubers in the study, it is indicated that in addition to the temperature treatment, the water potential of the growing medium also affected the performance of tubers by interacting with the temperature in determining the sprout vigor of the seed tubers. According to King and Stark (1997), excessive soil water at planting time also affects soil temperature which can lead to a decrease in sprout growth and delay the emergence of the seed tuber with older physiological age. In this study,sprout vigor was significantly increased at water potential treatment of -0.02 MPa especially when the ambient tem-perature reaches the optimum range. A similar response also recorded by MacKerron and Jeffries (1986) who found a decrease in the number of stems per plant from 5.0 to 4.7 when soil water potential at emergence decreased from -7 kPa to -70 kPa. Lack of available water will affect water uptake by the seed tuber (Svensson, 1977) required for the physiological processes in plants and as a medium for biochemical reactions (Taiz and Zeiger, 2002) such as the transport of soluble sugars to the growing buds. The biochemical reactions rate in the seed tubers increase at higher temperatures, so that the effect of the lack of water uptake associated with low water potential in the growing media will occur at higher temperatures. Enlarge-ment of the cells may also be affected by the availability of water, so that the higher water potential treatment associated with larger buds. These results may explain the advantage of cultivation practices of pre-plant water anagement in supporting a uniform germination (Pandey, 2007).

Response found in this study showed that when the temperature conditions at planting time is at the optimum range for sprouting reduction of soil moisture conditions can affect the vigor of shoots from potato tubers. From the evidence presented in this study it can be concluded that in addition to the factors already known in advance that influence the number of stems of potato plants, such as tuber size (number of buds per tuber), time and storage conditions, temperature and moisture at planting can also affect the number of sprout from seed tubers. Both of these factors seem to interact to alter the expression of the physiological status of the seed tubers in determining the performance of the tuber after planting.The results of this study also indicate the importance of soil moisture conditions at planting in tropical planting conditions where the averages of temperature in the highlands where these crops are usually grown are on a range optimum. According to Levy and Veilluex (2007) potato plants cultivated in the region of sub-tropical, semi-arid and arid will face high temperatures both at day and night, combined with the relatively drier atmosphere. In this condition cultivation techniques that can help plants to adapt to these conditions need to be considered. One is the conservation and water management techniques to improve the efficiency of water use by plants. Water conservation technique that is easily conducted is mulching. The use of mulch can reduce evaporation and maintain the ground water in addition to lowering the temperature of the soil. Hamdani (2009) found that straw mulching on potato crops grown in the mid altitude region (± 680 m asl) lower the temperature of the topsoil during the day about 6° C compared to the control treatment (31.5 ° C) and black plastic mulch (28.5 ° C).

Further study is necessary to the use of seed tubers with greater differences in physiological status given there is a possibility that the tubers used in this study were in a narrow range. Thus the interaction between environmental conditions at planting and the physiological status can be investigated in influencing the sprouting of seed tubers of potato plants that will ultimately determine the number of stems of plants, which is one factor that determines the quality of tubers produced.

CONCLUSION

Based on the results found in the recent study, it can be concluded that the sprouting of the seed tuber significantly influenced by temperature and soil water potential. There were no significant differences from the seed lot used in both of the number of sprouts produced and the vigor of the sprouts expressed as the sprouting capacity (fresh weight (FW) sprouts / FW tuber). Effect of water potential on sprout numbers was smaller then the effect of temperature andwas evident at low temperatures than higher temperatures. Sprout vigor increased with soil water potential with the greatest response seen in the highest temperature treatment. Temperature and water potential at planting interact significantly ($p < 0.01$) in influencing vigor or capacity of potato tubers sprout which shows greater influence of moisture conditions at high temperatures.

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