Correlation and path coefficient analysis of heat stress tolerance characters in potato

J Supriatna¹*, A Nuraeni¹, R Fajarfika¹ and J P Sahat²

¹ Study Program of Agrotechnology, Faculty of Agriculture, Universitas Garut, Garut, Indonesia
² Indonesian Vegetable Research Institute, Bandung Barat, Indonesia

* jajangsupriatna@uniga.ac.id

Abstract. Morphophysiological characters associated with yield in warm climate area can be used to determine heat stress tolerance characters. Correlation and path coefficient analysis were used to ascertain the relationship between morphophysiological characters and yield, and to estimate direct effects as well as indirect effects on them. Nine cultivars were evaluated in Garut, Indonesia which is situated at an altitude of 732 masl with an average air temperature of 28°C at noon and 23°C at night. Randomized complete block design was used in this experiment and it was performed in triplicate. As the result, correlation analysis indicated that plant height, leaf number, leaf area index, stomatal density, dry weight, tuber number, and tuber diameter showed positive relationship with yield, whereas chlorophyll content showed negative relationship with yield. Furthermore, path coefficient analysis indicated that plant height, leaf number, leaf area index, tuber number, and tuber diameter showed positive direct effect on yield. Path coefficient analysis also indicated indirect effects among characters. Plant height had positive indirect effect on yield through leaf number and leaf area index. Leaf number had positive indirect effect on yield through leaf area index, tuber number, and tuber diameter. Tuber number had positive indirect effect on yield through tuber area index, tuber number, and tuber diameter.

1. Introduction

Potato is an introduction plant which originate from South America and started to be cultivated in Indonesia in 1974. Potato can grow optimally in the area with cool temperature around 14 - 22°C, and it is sensitive to heat stress [1]. In Indonesia, potato is commonly planted in a high land area of more than 1000 meters above sea level. The area with suitable altitude to plant potato is limited and most of the area is a conservation forestry which is not allowed to have cultivation activities in that area. Another option to be utilized for cultivation is area with medium altitude (300-700 masl) which is widely available. The medium altitude area in Indonesia has sub-optimal conditions for potato growth. The temperature is generally higher than the requirement and that condition causes heat stress [2].

Heat stress significantly affect physiological process which is characterized by less photosynthesis, higher respiration, higher growth of haulm with assimilation more to the haulm, tuber disorder, shortening or omitting tuber dormancy, less dry content of tuber, and higher glycoalkaoid level [3]. Heat stress also influences leaf and branch assimilation distribution and canopy photosynthetic rate [4]. Heat stress can reduce the external and internal quality of tubers [5]. The previous studies also reported that heat stress can inhibit the growth and filling of tubers which directly impacts to the decreasing of yield [6,7].
The effects of heat stress on potatoes confront potato breeders with challenges to produce tolerant cultivars. Previous research indicated that it is possible to find genetic materials for breeding of heat stress tolerance obtained from wild *Solanum* species [8,9]. There are lines and cultivars which have potential tolerant character based on yield in medium altitude in Indonesia [2,10]. Previous research reported that the differences in tolerance levels can also be directly attributed to morphophysiological responses such as plant height, leaf area index, chlorophyll content, chlorophyll stability index, membrane stability index [11], haulm dry weight, stem thickness, leaf area index, leaf/stem weight ratio, number of tubers per plant, mean tuber weight, tuber yield, heat susceptibility index, heat tolerance index, chlorophyll index, photosynthetic rate and stomatal conductance [12].

The determination of morphophysiological characters in order to maximize the yield in warm climate area is important in designing an effective heat stress tolerance breeding program. Furthermore, an analysis of the association among various characters helps to identify which characters are the most important in order to select genetic materials. Correlation analysis provides information about the magnitude relationship among characters but it may not give an exact picture of the relative importance of direct and indirect influences for each component characters. However, Path coefficient analysis allows to identify the direct, indirect, and as well as to remove any spurious effect which may be present [13]. The aim of this study was to estimate the correlation and path coefficient between morphophysiological characters with yield in warm climate area in order to determine heat stress tolerance character.

2. Materials and methods

2.1. Genetic materials and evaluation site
Nine potato cultivars from Indonesian Vegetable Research Institute were used for this study. They are Olympus, Granola, Andina, Cipanas, Atlantik Malang, Amabile, GM-08, Vernei, and Median. The cultivars were identified have characteristic maintain yield in warm climate area. The experiment was performed in dry season from July 2018 up to September 2018 in Tarogong, Garut, Indonesia at 732 meters above sea level. The air temperature in experimental field was 28°C at noon and 23°C at night. The soil was classified as inceptisols with an average soil temperature of 26°C at noon and 24°C at night. The climate is a type C based on the classification by Schmit dan Fergusson.

2.2. Statistical analysis
The experiment was arranged in a randomized complete block design which consist 3 replications and nine potato cultivars as treatment. The morphophysiological characters observed were plant height, leaf number, leaf area index, stomatal density, chlorophyll content, dry weight, tuber number, tuber diameter, and yield. Correlation coefficients among characters were done using SPSS version 20.0 for Windows. Path coefficient analysis is used to find out which morphophysiological characters have direct or indirect influence to yield [13].

3. Results and discussion

3.1. Correlation analysis
Correlation coefficients among characters are presented in Table 1. Correlation coefficients showed both positive and negative correlations between morphophysiological characters and yield. The morphophysiological characters that have a significant positive correlation are plant height (r = 0.658), leaf number (r = 0.872), leaf area index (r = 0.760), stomatal density (r = 0.422), dry weight (r = 0.832), tuber number (r = 0.486), and tuber diameter (r = 0.769). Whereas, the character which has a significant negative correlation is the chlorophyll content (r = -0.594). The positive correlation indicates that the higher character value will cause an increase yield. Conversely, the negative correlation indicates that the higher the character value will cause a decrease yield.
Table 1. Correlation coefficient among characters.

| Character | Ph | Ln | Lai | Sd  | Cc  | Dw  | Tn | Td | Y  |
|-----------|----|----|-----|-----|-----|-----|----|----|----|
| Ph        | 1  | 0.634 b | 0.337 b | 0.492 b | -0.178 | 0.756 b | 0.535 b | 0.537 b | 0.658 b |
| Ln        | 1  | 0.773 b | 0.290 b | -0.599 b | 0.931 b | 0.322 b | 0.717 b | 0.872 b |
| Lai       | 1  | 0.254 a | -0.683 b | 0.641 b | 0.200 | 0.778 b | 0.760 b |
| Sd        | 1  | -0.376 b | 0.423 b | 0.598 b | 0.370 b | 0.422 b |
| Cc        | 1  | -0.500 b | -0.203 b | -0.533 b | -0.594 b |
| Dw        | 1  | 0.365 b | 0.696 b | 0.832 b |
| Tn        | 1  | 0.309 b | 0.486 b |
| Td        | 1  | 0.769 b |
| Y         | 1  |

a Significant at 5% level of probability
b Significant at 1% level of probability
Ph = plant height; Ln = leaf number; Lai = leaf area index; Sd = stomatal density; Cc = chlorophyll content; Dw = dry weight; Tn = tuber number; Td = tuber diameter; Y = yield.

Demirel et al, has reported that several morphophysiological characters positively correlated with yield in high temperature condition, namely dry weight, leaf area index, and stomatal conductance [12]. Nagarajan and Minhas have reported that stem elongation which increases haulm characters, namely plant height, leaf number and dry weight in high temperature conditions potentially increased yield [14]. Heat stress tolerance is characterized by the ability to maintain the growth of haulm and tubers under high temperatures through balanced partition. It facilitates to support of haulm which maintains photosynthesis and allows the accumulation of dry matter in filling tubers. Diverse result has been reported by Paul et al, which showed that plant height and leaf area index negatively correlated with yield in high temperature condition [11]. Correlation between characters in heat stress conditions does not show definite results. Reynolds and Ewing has reported that cultivar difference causes correlation value between induction of leaf toward tuberize and yield were not always correlated [15].

3.2. Path coefficient analysis

The result of path coefficient analysis showing the direct and indirect effects of morphophysiological characters on yield presented in Table 2. Plant height, leaf number, leaf area index, tuber number and tuber diameter have positive direct effects on yield, while stomatal density, chlorophyll content and dry weight do not have direct effect on yield. Leaf number has the highest positive direct effect (0.221) on yield followed by leaf area index (0.221), tuber diameter (0.070), plant height (0.065) and tuber number (0.042). The results indicate that the increasing value of these characters will increase the yield in heat stress conditions.

Table 2. Path coefficient analysis shows the direct and indirect effects of morphophysiological characters on yield.

| Character | Direct effect | Indirect effect | Total effect |
|-----------|--------------|----------------|-------------|
|            | Ph | Ln | Lai | Sd | Cc | Dw | Tn | Td |
| Ph        | 0.065 | 0.152 | 0.054 | - | - | - | - | 0.271 |
| Ln        | 0.221 | - | 0.026 | - | - | 0.082 | 0.034 | 0.363 |
| Lai       | 0.097 | - | - | - | - | - | - | 0.097 |
| Sd        | - | - | - | - | - | - | - | - |
| Cc        | - | - | - | - | - | - | - | - |
| Dw        | - | - | - | - | - | - | - | - |

Table 2. Cont.
The results of the study also showed that some characters have indirect effects on yield (Table 2). Plant height had positive indirect effect on yield through leaf number (0.152) and leaf area index (0.054). Leaf number had positive indirect effect on yield through leaf area index (0.026), tuber number (0.082), and tuber diameter (0.034). Tuber number had positive indirect effect on yield through tuber diameter (0.034). The high value of indirect influence usually has a high correlation value (Figure 1). According to Dewey and Lu if the total influence value is high but the value of the direct effect is small then the characters with an indirect effect can be considered as selection criteria [16].

![Path coefficient diagram](image)

**Figure 1.** Path coefficient diagram of morphophysiological characters on yield.

The residual value is the total value of the direct and indirect effects of characters which have not been identified in increasing yield under heat stress conditions. If the residual value approaches zero, it means that the selected characters are the criteria of selection which is effective in developing high yield potato cultivars under heat stress conditions. The results of this study indicate that the residual value reaches 0.123, which means that 12.3% of influence from other factors has not been identified.

### 4. Conclusion

Correlation analysis indicated that plant height, leaf number, leaf area index, stomatal density, dry weight, tuber number, and tuber diameter showed positive relationship with yield, whereas chlorophyll content showed negative relationship with yield. Furthermore, path coefficient analysis indicated that plant height, leaf number, leaf area index, tuber number, and tuber diameter showed positive direct effect on yield. Path coefficient analysis also indicated indirect effects among characters. Plant height had positive indirect effect on yield through leaf number and leaf area index. Leaf number had positive
indirect effect on yield through leaf area index, tuber number, and tuber diameter. Tuber number had positive indirect effect on yield through tuber diameter. In conclusion, plant height, leaf number, leaf area index, tuber number, and tuber diameter are the primary morphophysiological characters selected for selection genetic material of heat stress tolerance characters in order to develop high-yield potato cultivars in warm climate area.

Acknowledgement
The author would like to put into words their appreciation to the Ministry of Higher Education and Research Technology of Republic Indonesia for funding the research through PDP Grant No. 202/R/UNIGA/V/2018 given to the 1st author and Faculty of Agriculture Universitas Garut and also for funding the registration and accommodation in order to participate the AASEC 2019.

References
[1] Makarova S, Makhotenko A, Spechenkova N, Love A J, Kalinina N O and Taliensky M 2018 Interactive responses of potato (Solanum tuberosum L.) plants to heat stress and infection with potato virus Y Frontiers in Microbiology 9 pp 1-14
[2] Supriatna J, Fajarifika R, Bagja A and Sahat J P 2018 Seleksi kultivar kentang (Solanum tuberosum L.) berdasarkan penampilan karakter agronomis di dataran medium Kabupaten Garut JAGROS : Jurnal Agroteknologi dan Sains 3 (1) pp 1-10
[3] Levy D and Veilleux R E 2007 Adaptation of potato to high temperatures and salinity - a review American Journal of Potato Research 84 (6) pp 487–506
[4] Fleisher D H, Timlin D J and Reddy V R 2006 Temperature influence on potato leaf and branch distribution and on canopy photosynthetic rate Agronomy Journal 98 (6) pp 1442-1452
[5] Sterret S B, Henninger M R and Lee G S 1991 Relationship of internal heat necrosis of potato to time and temperature after planting Journal of the American Society for Horticultural Science 116 (4) pp 697-700
[6] Wheeler R M, Steffen K L, Tibbitts T W and Palta J P 1986 Utilization of potatoes for life support systems. II. The effects of temperature under 24-H and 12-H photoperiods American Potato Journal 63 (11) pp 639-647
[7] Rykaczewska K 2015 The effect of high temperature occurring in subsequent stages of plant development on potato yield and tuber physiological defects American Journal of Potato Research 92 (3) pp 339–349
[8] Gautney T L and Haynes F L 1983 Recurrent selection for heat tolerance in diploid potatoes (Solanum tuberosum subsp. Phureja and Stenotomum) American Potato Journal 60 (7) pp 537-542
[9] Midmore D J and Prange R K 1991 Sources of heat tolerance amongst potato cultivars, breeding lines and Solanum species Euphytica. 55 (3) pp 235-245
[10] Prabaningrum L, Moeckasan T K., Sulastrini I, Handayani T, Sahat J P, Sofiari and E, Gunadi N 2014 Teknologi budidaya kentang di dataran medium (Bandung Barat: Indonesian Vegetable Research Institute)
[11] Paul S, Bose I and Gogoi N 2016 Morphophysiological responses: criteria for screening heat tolerance in potato Current Science 111 (7) pp 1226-1231
[12] Demirel U, Çalışkan S, Yavuz C, Tindas I, Polgar Z, Vaszily Z, Cernák I, Çalışkan M E 2017 Assessment of morphophysiological traits for selection of heat-tolerant potato genotypes Turkish Journal of Agriculture And Forestry 41 pp 218-232
[13] Hill W G, Singh R K and Chaudhary B D 1978 Biometrical methods in quantitative genetic analysis JSTOR 34 (4) p 723
[14] Nagarajan S and Minhas J S 1995 Intemodal elongation: a potential screening technique for heat tolerance in potato Potato Research 38 (2) pp 179-186
[15] Reynolds M P, Ewing E E 1989 Heat tolerance in tuber bearing Solanum species: a protocol for screening American Potato Journal 66 (2) pp 63-74
[16] Dewey D R and Lu K H 1959 A correlation and path coefficient analysis of components of crested wheat seed production *Agronomy Journal* **51** (9) pp 515-518