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Combination of irrigation systems in several soil types using principal component analysis

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Abstract

This study aims to determine the effectiveness of Principal Component Analysis in evaluating irrigation systems in different soil types and to obtain information on the best method and combination of factors for rice cultivation. The study was carried out in Soppeng Regency in April-September 2019. A nested design was used with different replication of soil texture levels (S), namely sandy (S1), loam (S2), and clay (S3). The second factor was water management (W), which consists of farmers' watering practice (W1), as well as intermittent (W2), dry-wet application (W3), and semi-puddled (W4) irrigation systems. Each combination treatment was replicated three times to obtain 36 experimental units. Subsequently, observations were carried out on seven yield component parameters, analyzed with multivariate evaluation, correlation, and principal component analysis. The principal component analysis effectively assessed irrigation methods and soil types with an eigenvalue of 0.9286. The intermittent irrigation system was the best method for rice cultivation, specifically in loam and clay soils, where the latter had the best combination. These results are expected to be a basis for future studies or practical activities on the crop's cultivation.

Keywords: Irrigation system, Oryza sativa, PCA, Soil texture.
Abbreviations (if any): (PCA_principal component analysis, PC_principal component, PH_plant height, NUG_number of unfilled grains, NT_number of tillers, NTG_number of total grains, W1000G _weight of 1000 grains.

Introduction

The paddy field is a unique farming system that is often used on a specific commodity, namely rice because it can meet the crops' requirements in terms of soil preparation, water management, and its impact on the environment (FAO, 2011). However, special attention must be paid to inland tillage while managing the field. Hardjowigeno (1993) reported that paddy soil has a pale-colored surface horizon due to the reduction of Fe and Mn from field puddling, which leads to the transfer and deposit of compounds in the soil particle structure and root hairs. It can also produce approximately 90% of rice yield, which is decreasing due to the conversion of land for non-agricultural purposes. Rain-fed paddy fields, dryland farms, and tidal land are present in significant areas across regions that have not contributed optimally to the crop's production (FAO, 2011). The management of irrigated areas must consider various aspects to increase and stabilize rice production in Indonesia.

Paddy has a high demand for water in the plant's life circle. De Datta (1981) reported that it requires approximately 800-1200 mm season^{-1}, or 6-10 mm day^{-1}. This finding is in line with a statement that the irrigation control in paddy is important to increase the yield. The excess puddle system is the most used management method by farmers, but it is wasteful and reduces root development. Consequently, it needs to be changed with more efficient method, but the effectiveness of irrigation systems still depends on field's texture.

Soil can be categorized based on their color, which includes red and black as well as their texture, namely sandy, silt, and clay. Furthermore, soilw containing more sand, silt, and clay components have macropores, mesopores, and micropores, respectively, with descending degrees of porosity (Firoozi et al., 2016). The type of irrigation and tillage system used on them also depends on their texture. Wang et al. (2016), Mamedov et al. (2017) and Herawati et al. (2020) stated that effective water management can increase the growth and productivity of rice in sandy soil. The use of intermittent irrigation significantly affected vegetative growth, the number of panicles, the weight of 1000 seeds, and yields per hectare. Therefore, the study on the combination of irrigation control and soil type is expected to increase the productivity of paddy.

The principal component analysis is an evaluation method that can combine several characters and produce new variants with fewer dimensions. The result of the process still covers most of the existing diversity, hence, it can be used in multivariate analysis. It can also be used for mapping while assessing the cropping process, specifically on interrelated characters. Farid et al. (2021) and Anshori et al. (2021) reported that PCA-based mapping is effective in evaluating rice cultivation on these characters. Din et al. (2021) and Shi et al. (2021) also used the method to evaluate the relationship between genotypes on the morphology and post-harvest quality of rice. Farid et al. (2020) mapped wheat selection characters that are related to the main characteristics of productivity using PCA analysis. These findings indicate that the approach can be used for evaluating the combination of irrigation treatments and soil types in rice cultivation. Therefore, this study aims to determine the effectiveness of PCA analysis in assessing irrigation systems for different soil types as well as to obtain information about the best method and combination of both factors in rice cultivation.

Results

The correlation analysis between agronomy characters

Figure 1 shows the results of the correlation analysis, where the weight of 1000 grains, the number of tillers, and plant height were positively correlated to productivity with p-values of 0.60, 0.77, and 0.92, respectively. The three parameters also have a significant correlation with each other. Furthermore, the plant height correlated with weight of 1000 grains and the number of tillers with p-values of 0.63 and 0.82, respectively. The grains' weight had a significant correlation with the number of tiller with p-value of 0.71. The number of filled grains also correlated with the unfilled and total grains with p-values of -0.58 and 0.81, respectively.

The principal component analysis of the yield and the supporting characters of the yield

The principal component analysis results showed that PC1 and PC2 have variance proportion of 0.8078 and 0.1208, respectively. All the characters on PC1 have eigenvectors with relatively same size and direction. Meanwhile, the difference in the direction of variance was visible in PC2. The plant height (-0.3672) has the same direction as productivity (-0.4319) and the weight of 1000 grains has a similar association (0.8185) with the number of tillers (0.093). The PC1 and PC2 analysis results served as the basis for mapping the combination of irrigation methods and soil types, as shown in Table 2. The analysis showed that all irrigation treatments on clay soil had the highest PC1 value, while the W4 treatment on loam has the best PC2 value.

The mapping graph of PC1 and PC2

Figure 2 shows the results of PC1 and PC2 mapping, where the treatment of clay had a narrow or concentrated diversity of irrigation methods. Furthermore, its diversity was lower compared to loam and sandy soil. The PC1 value in the combination of sandy and loam against the irrigation method was negative, except for W4 and W1 Loam.

Discussion

The results of the correlation analysis showed that productivity had a very significant positive correlation with the number of tillers, plant height, and weight of 1000 grains. Several studies also reported the association between the number of tillers and the weight of 1000 grains on productivity (Saleh et al., 2020; Sadimantara et al., 2021). However, the correlation between plant height and productivity has shown overwhelming results. Wattoo et al. (2010) and Zhao et al. (2019) reported that the parameters correlate with each other, while Saleh et al. (2020) and Sadimantara et al. (2021) revealed that they do not have a relationship. Al-Salim et al. (2016) stated that plant height has a significant negative correlation with productivity. This finding indicates that its response is highly dependent on the environment and genetics. Wang et al. (2016), Ma et al. (2016), and Zhou et al. (2016) revealed that the height of rice plants is very sensitive to environmental changes, specifically differences in water availability conditions. These results showed that it can serve as a supporting character for productivity along with the number of tillers and weight of 1000 grains during evaluation. Its supportive characteristics can also be combined in the assessment and mapping of irrigation methods combination and soil types in rice production. The data and correlation are often assessed using the principal component analysis.

The PCA analysis results showed that PC1's proportion of variance was greater than 0.8. Jolliffe and Cadima (2016), Anshori et al. (2021) revealed that the optimal PC is used when the cumulative proportion is up to 0.8. This indicates that PC1 can represent the combination of the four characters in the analysis. The direction and magnitude of the eigenvectors between variables were also relatively the same. Consequently, PC1 is relevant in PCA analysis, but the use of PC2 as another dimension is also necessary. This was indicated by the eigenvector values between the four characters on PC2, which were not uniform and in the same direction to allow their combination to form a detailed diversity mapping graph, as shown in Figure 2 (Shetty et al., 2020; Farid et al., 2021).

Figure 2 shows that the clay soil has a narrow diversity, but it has a large PC1 mean. This indicates that the diversity of irrigation methods has no significant effect on plant growth. Clay soil is characterized by its high water-binding ability (Firoozi et al., 2016) and resistance (Mamedov et al., 2017; Herawati et al., 2020). Consequently, the application of irrigation methods does not affect its potency in supporting the growth of rice plants. The use of limited water, specifically in the intermittent concept also increases its growth potential and productivity compared to excess water. This is illustrated in Figure 2, where W2, W3, and W4 clay are in quadrant four, which is very similar to productivity and plant height. The application of irrigation system in loam and sandy soils showed various responses to the rice growth. This is because they have low water binding capacity and resistance compared to clay (Mamedov et al., 2017; Herawati et al., 2020). The diversity of growth in both types of soil depends on the interaction between their ability to bind with water and the time of irrigation for the crop. Based on these findings, the use of clay soil is the right choice for rice cultivation in Indonesia,

Table 1. Analysis of the principal components in the important characteristics of rice growth.

Characters	PC1	PC2	PC3	PC4
Plant height	0.5248	-0.3672	0.1375	0.7555
Weight of 1000 Grains	0.448	0.8185	0.359	0.0212
Productivity	0.5128	-0.4319	0.3825	-0.6358
Number of tillers	0.5107	0.093	-0.8402	-0.1567
Proportion of Variance	0.8078	0.1208	0.0535	0.0178
Cumulative Proportion	0.8078	0.9286	0.9822	1.0000
EigenValues	3.2313	0.4833	0.2141	0.0713

Notes: PC= principal component

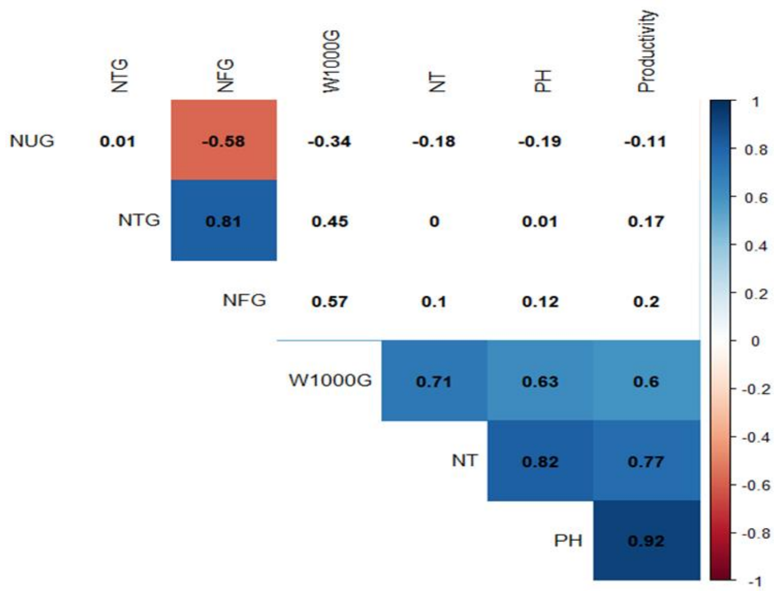

Fig 1. Correlation analysis among rice agronomy characters (The color sign showed a significant correlation at the 5% error level, PH= plant height, W1000G = weight of 1000 grains, NT= number of tillers, NFG = number of filled grains, NUG = number of unfilled grains, NTG = number of total grains).

Table 2. Standardization and PCA values on the character of productivity and correlated productivity.

Treatment	Real Value				Standardization (z value)				PCA	
	PH	NT	W1000G	productivity	PH	NT	W1000G	productivity	PC1	PC2
W1Sandy	82.3	25	24.07	6.8	-0.84	-2.00	-1.94	-1.53	-3.11	-0.80
W2Sandy	79.13	22.3	25	6.53	-2.65	-3.74	1.26	-2.30	-3.92	2.65
W3Sandy	80.4	27.03	24.87	6.5	-1.93	-0.68	0.81	-2.39	-2.22	2.34
W4Sandy	79.3	20.6	23.3	6.37	-2.56	-4.84	-4.59	-2.77	-7.29	-2.07
W1Loam	84.53	29.67	25.23	6.57	0.43	1.03	2.05	-2.19	0.55	2.56
W2Loam	79.9	22.67	22.67	6.97	-2.21	-3.51	-6.75	-1.03	-6.51	-4.59
W3Loam	78.37	29	24	6.77	-3.09	0.59	-2.18	-1.61	-3.12	0.10
W4Loam	80.33	27	25.43	7.4	-1.97	-0.70	2.74	0.21	-0.06	2.81
W1Clay	90.3	38.33	25.83	8.63	3.73	6.63	4.11	3.76	9.11	0.99
W2Clay	93.4	34.67	25	8.9	5.50	4.26	1.26	4.54	7.95	-2.55
W3Clay	93.57	32.67	25.57	9.17	5.59	2.97	3.22	5.32	8.62	-1.44
W4Clay	91.97	31.67	25.77	9.6	4.68	2.32	3.91	6.56	8.76	-1.14

Notes: PH = plant height, NT= number of tillers, W100G= weight of 1000 grains, PCA = Principal component analysis, PC= principal component.

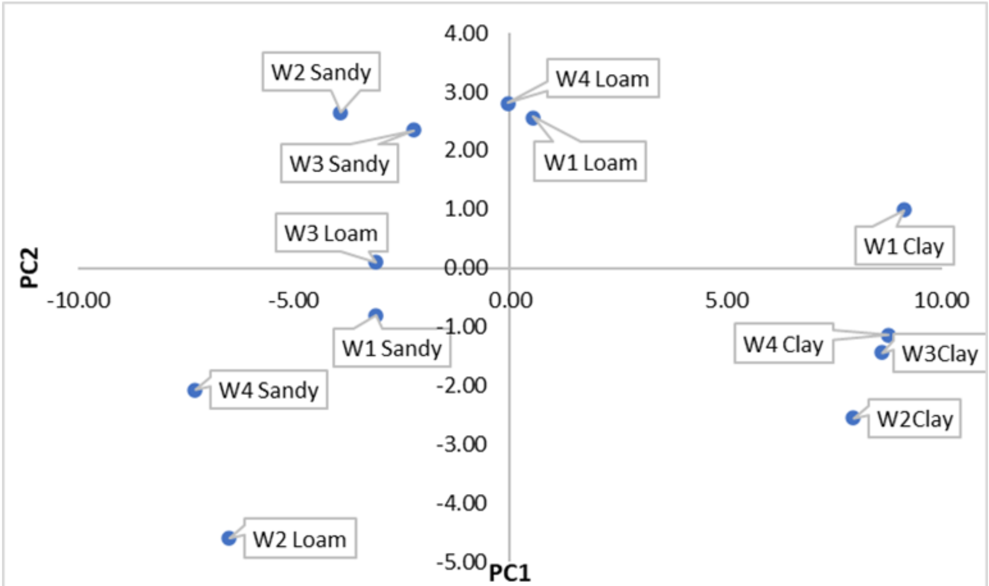

Fig 2. Two-dimensional mapping of Principal Component (PC)1 and PC2 against irrigation method (W) and soil type (W1_ farmers' watering practice, W2 _ intermittent, W3_ dry-wet application (AWD), W4_ semi puddled).

Specifically when combined with intermittent water supply (W2).

The results showed that the interaction assessment through principal component analysis was very effective. It can also accommodate several characters with the same direction of diversity. This finding is consistent with the studies carried out by Anshori et al. (2021), and Farid et al. (2021). The PCA assessment can map the differences between objects and characters with significant correlation, as reported by Farid et al. (2020). However, this method needs to be combined with machine learning concepts, which require large objects (Dijk et al., 2020). Their combination is expected to further increase the precision in decision-making. The results of this study can serve as a good basis for developing a cultivation assessment based on principal component analysis in the future

Materials and Methods

This study was carried out in Soppeng Regency on three types of soil, namely clay, loam, and sandy from April-September 2019. The locations used were areas with equatorial rain type and peaks in December/January as well as April/May. The determination of paddy fields was based on the farmers that accepted the introduced technology.

Experimental design and statistical analysis

The study explored the irrigated paddy fields of farmers using a 1:2 Legowo planting system. This study was arranged by the nested randomized complete block design, where the replications nesting to different soil texture levels (S), namely sandy (S1), loam (S2), and clay (S3). The main factor was water management (W), which consists of farmers' watering practice (W1) as well as intermittent (W2), dry-wet application (AWD) (W3) and semi puddled (W4) irrigation systems. Each combination treatment was replicated three times to obtain a total of 36 experimental units.

Study procedure

The activities started with soil tillage using a hand tractor to prepare the field for planting. They were then divided into 36 plots of 100 m x 27 m, hence, a total of 1 hectare of land was used. Before planting, the seeds' germination process took three days, after which they were sown on separate fields and trays. Subsequently, they were transplanted after 11-14 days using a transplanter. The plant maintenance involves replanting based on their conditions as well as the application of fertilizer based on the leaf green color level reading results, which were obtained before tillage and harvesting. The addition of urea fertilizer was carried out with the color chart indicator, after which pest and disease control was performed. Weeding was also conducted using herbicides and physical means, and water was then provided after the treatments.

Observation and data analysis

The parameter observed include plant height, the weight of 1000 grains, productivity, number of tillers as well as the number of filled, unfilled, and total grains. They were then analyzed using multivariate evaluation, which consists of correlation and principal component analysis (PCA). The correlation analysis was carried out for all parameters using Rstudio with the corrplot package. Meanwhile, PCA was used for others that correlated significantly to productivity with the STAR 2.0.1 software. All combination treatments were formulated into PC1 and PC2 as the basis for the plot analysis, after which they were plotted in 2 dimensions (Anshori et al., 2021)

Conclusion

The use of multi-character based on principal component analysis is considered to be effective in evaluating the combination of irrigation methods and soil types. Plant characters, such as height, number of tillers, and weight of 1000 seeds can be used as selection criteria that support the productivity potential of their combination. An intermittent irrigation system is the best method for rice cultivation, specifically in loam and clay soils, where the latter had the best combination. These results can be used as references and recommendations for further studies or practical activities on rice cultivation.

References

Anshori MF, Purwoko BS, Dewi IS, Ardie SW, Suwarno WB (2021) A new approach to select doubled haploid rice lines under salinity stress using indirect selection index. Rice Sci. 28: 368-378.

Al-Salim SHF, Al-Edelbi R, Aljbory F, Saleh, MM (2016) Evaluation of the performance of some rice (Oryza sativa L.) varieties in two different environments. Open Access Lib J. 3: e2294.

De Datta SK (1981) Principles and Practices of Rice Production. John Wiley & Sons Inc, Singapore. 317.

Dijk ADJV, Kootstra G, Kruijer W, Ridder DD (2020) Machine learning in plant science and plant breeding. iScience. 24: 101890.

Din M, Rashid M, Fahad M, Ahmad I, Bibi N, Mahboob W, Khan A (2021) Multivariate analysis of rice genotypes for seeding traits' characterization and evaluation. Pak J Bot. 53: 613-619.

FAO (2011) The State of The World's Land and Water Resources for Food and Agriculture (SOLAW) – Managing Systems at Risk. Food and Agriculture Organization of the United Nations, Rome and Earthscan, London. 14-15.

Farid M, Nasaruddin, Musa Y, Anshori MF, Ridwan I, Hendra J, Gatot S (2020) Genetic parameters and multivariate analysis to determine secondary traits in selecting wheat mutant adaptive on tropical lowlands. Plant Breed Biotech. 8: 368-377.

Farid M, Nasaruddin, Anshori MF, Musa Y, Iswoyo H, Sakinah AI (2021) Interaction of rice salinity screening in germination and seedling phase through selection index based on principal components. Chil J Agric Res. 81: 368-377.

Firoozi AA, Firoozi AA, Baghini MS (2016) A review of clayey soils. Asian J Appl Sci. 4: 1319-1330.

Hardjowigeno S (1993) Soil of paddy field. Post Graduate Program, IPB University, Bogor. (In Indonesian)

Herawati A, Mujiyo, Syamsiyah J, Baldan SK, Arifin I (2020) Application of soil amendments as a strategy for water holding capacity in sandy soils. IOP Conf Series: Earth and Environ Sci. 724: 012014.

Jolliffe IT, Cadima J (2016) Principal component analysis: A review and recent developments. Philos Trans Royal Soc A. 374: 20150202.

Ma X, Feng F, Wei H, Mei H, Xu K, Chen S, Li T, Liang X, Liu H, Luo L (2016) Genome-wide association study for plant height and grain yield in rice under contrasting moisture regimes. Front Plant Sci. 7:1801.

Mamedov AI, Huang C, Aliev FA, Levy GJ (2017) Aggregate stability and water retention near saturation characteristics as affected by soil texture, aggregate size and polyacrylamide application. Land Degrad Dev. 28: 543–552.

Sadimantara GR, Yusuf DN, Febrianti E, Leomo S, Muhidin (2021) The performance of agronomic traits, genetic variability, and correlation studies for yield and its components in some red rice (*Oryza sativa*) promising lines. Biodiversitas. 22: 3994-4001.

Saleh MM, Salem KFM, Elabd AB (2020) Definition of selection criterion using correlation and path coefficient analysis in rice (*Oryza sativa* L.) genotypes. Bull Natl Res Cent. 44: 143.

Shetty DK, Acharya UD, Narendra VG, Prajual PJ (2020) Intelligent system to evaluate the quality of DRC using image processing and then categorize using artificial neural network (ANN). Indian J Agric Res. 54: 716-723.

Shi S, Wang E, Li C, Zhou H, Cai M, Cao C, Jiang Y (2021) Comprehensive evaluation of 17 qualities of 84 types of rice based on principal component analysis. Foods. 10: 2883.

Wang JX, Sun J, Li CX, Liu HL, Wang JG, Zhao HW, Zou DT (2016) Genetic dissection of the developmental behavior of plant height in rice under different water supply conditions. J Integr Agric. 15: 2688–2702.

Wattoo JI, Khan AS, Ali Z, Babar M, Naeem M, Ullah MA, Hussain N (2010) Study of correlation among yield related traits and path coefficient analysis in rice (*Oryza sativa* L.). AfrJ Biotechnol. 9: 7853-7856.

Zhao H, Mo Z, Lin Q, Pan S, Duan M, Tian H, Wang S, Tang X (2020) Relationships between grain yield and agronomic traits of rice in Southern China. Chil J Agric Res. 80: 72-79.

Zhou L, Liu S, Wu W, Chen D, Zhan X, Zhu A (2016) Dissection of genetic architecture of rice plant height and heading date by multiple-strategy-based association studies. Sci Rep. 6:29718.