

1 **Submission Draft**

2 **Combination of Irrigation Systems in Several Soil Types Based Using Principal Component**
3 **Analysis**

4
5 **Amir Yassi^{1*}, Hari Iswoyo¹, Muhammad Fuad Anshori¹**

6
7 ¹Department of Agronomy, Faculty of Agriculture, Hasanuddin University, Perintis

8 Kemerdekaan Street Km 10, Makassar, South Sulawesi, 90245, Indonesia

9 Street Km 10, Makassar, South Sulawesi, 90245, Indonesia

10 *Corresponding author: amiryassi.22@gmail.com

11
12 **Abstract.** This study aims to determine the effectiveness of Principal Component Analysis in
13 evaluating irrigation systems for different soil types and obtain information about the best
14 method and combination of factors for rice cultivation. The study was carried out in Soppeng
15 Regency in April-September 2019. A nested design was used with different replication of soil
16 texture levels (S), namely sandy (S1), loam (S2), and clay (S3). The second factor was water
17 management (W), which consists of farmers' watering practice (W1), as well as intermittent
18 (W2), dry-wet application (W3), and semi-puddled (W4) irrigation systems. Each combination
19 treatment was replicated three times to obtain 36 experimental units. Subsequently, observations
20 were carried out on seven yield component parameters, analyzed with multivariate evaluation,
21 correlation, and principal component analysis. The principal component analysis effectively
22 assessed irrigation methods and soil types with an eigenvalue of 0.9286. The intermittent
23 irrigation system was the best method for rice cultivation, specifically in loam and clay soils,

24 where the latter had the best combination. These results are expected to be a basis for future
25 studies or practical activities on the crop's cultivation.

26 **Key words:** Irrigation system, *Oryza sativa*, PCA, Soil texture

27 **Abbreviations** (if any): (PH= plant height, W1000G = weight of 1000 grains, NT= number of
28 tillers, NFG = number of filled grains, NUG = number of unfilled grains, NTG = number of total
29 grains, PCA = principal component analysis, PC = principal component

30

31 **Introduction**

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

43 Paddy has a high demand for water in the plant's life circle, and this is consistent with De
44 Datta (1981) that it requires approximately 800-1200 mm season⁻¹, or 6-10 mm day⁻¹. This
45 finding is in line with a statement that the irrigation control in paddy is important to increase its
46 yield. The excess puddle system is the most used management method by farmers, but it is

47 wasteful and reduces root development. Consequently, it needs to be changed with a more
48 efficient method, but the effectiveness of irrigation systems still depends on field's texture.

49 Soil can be categorized based on their color, which includes red and black as well as their
50 texture, namely sandy, silt, and clay. Furthermore, soil containing more sand, silt, and clay
51 components have macropores, mesopores, and micropores, respectively, with descending
52 degrees of porosity (Firoozi et al., 2016). The type of irrigation and tillage system used on them
53 also depends on their texture. Wang et al. (2016), Mamedov et al. (2017) and Herawati et al.
54 (2020) stated that effective water management can increase the growth and productivity of rice in
55 sandy soil. The use of intermittent irrigation significantly affected vegetative growth, the number
56 of panicles, the weight of 1000 seeds, and yields per hectare. Therefore, the study on the
57 combination of irrigation control and soil type is expected to increase the productivity of paddy.

58 The principal component analysis is an evaluation method that can combine several characters
59 and produce new variants with fewer dimensions. The result of the process still covers most of
60 the existing diversity, hence, it can be used in multivariate analysis. It can also be used for
61 mapping while assessing the cropping process, specifically on interrelated characters. Farid et al.
62 (2021) and Anshori et al. (2021) reported that PCA-based mapping is effective in evaluating rice
63 cultivation on these characters. Din et al. (2021) and Shi et al. (2021) also used the method to
64 evaluate the relationship between genotypes on the morphology and post-harvest quality of rice.
65 Farid et al. (2020) mapped wheat selection characters that are related to the main characteristics
66 of productivity using PCA analysis. These findings indicate that the approach can be used for
67 evaluating the combination of irrigation treatments and soil types in rice cultivation. Therefore,
68 this study aims to determine the effectiveness of PCA analysis in assessing irrigation systems for

69 different soil types as well as to obtain information about the best method and combination of
70 both factors in rice cultivation.

71

72 **Results**

73

74 Figure 1 shows the results of the correlation analysis, where the weight of 1000 grains, the
75 number of tillers, and plant height positively correlated to productivity with p-values of 0.60,
76 0.77, and 0.92, respectively. The three parameters also have a significant correlation with each
77 other. Furthermore, the plant height correlated with weight of 1000 grains and the number of
78 tillers with p-values of 0.63 and 0.82, respectively. The grains' weight had a significant
79 correlation with the number of tiller with p-value of 0.71. The number of filled grains also
80 correlated with the unfilled and total grains with p-values of -0.58 and 0.81, respectively.

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

89 Figure 2 shows the results of PC1 and PC2 mapping, where the treatment of clay had a
90 narrow or concentrated diversity of irrigation methods. Furthermore, its diversity was lower

91 compared to loam and sandy soil. The PC1 value in the combination of sandy and loam against
92 the irrigation method was negative, except for W4 and W1 Loam..

93 **Discussion**

94
95 The results of the correlation analysis showed that productivity had a very significant positive
96 correlation with the number of tillers, plant height, and weight of 1000 grains. Several studies also
97 reported the association between the number of tillers and the weight of 1000 grains on
98 productivity (Saleh et al., 2020; Sadimantara et al., 2021). However, the correlation between plant
99 height and productivity has mixed results. Wattoo et al. (2010) and Zhao et al. (2019) reported that
100 the parameters correlate with each other, while Saleh et al. (2020) and Sadimantara et al. (2021)
101 revealed that they do not have a relationship. Al-Salim et al. (2016) stated that plant height has a
102 significant negative correlation with productivity. This finding indicates that its response is highly
103 dependent on the environment and genetics. Wang et al. (2016), Ma et al. (2016), and Zhou et al.
104 (2016) revealed that the height of rice plants is very sensitive to environmental changes,
105 specifically differences in water availability conditions. These results showed that it can serve as
106 a supporting character for productivity along with the number of tillers and weight of 1000 grains
107 during evaluation. Its supportive characteristics can also be combined in the assessment and
108 mapping of irrigation methods combination and soil types in rice production. The data and
109 correlation are often assessed using the principal component analysis.

110 The PCA analysis results showed that PC1's proportion of variance was greater than 0.8. Jolliffe
111 and Cadima (2016), Anshori et al. (2021) revealed that the optimal PC is used when the cumulative
112 proportion is up to 0.8. This indicates that PC1 can represent the combination of the four characters
113 in the analysis. The direction and magnitude of the eigenvectors between variables were also

114 relatively the same. Consequently, PC1 is relevant in PCA analysis, but the use of PC2 as another
115 dimension is also necessary. This was indicated by the eigenvector values between the four
116 characters on PC2, which were not uniform and in the same direction to allow their combination
117 to form a detailed diversity mapping graph, as shown in Figure 2 (Shetty et al., 2020; Farid et al.,
118 2021).

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

133 The results showed that the interaction assessment through principal component analysis was
134 very effective. It can also accommodate several characters with the same direction of diversity.
135 This finding is consistent with the studies carried out by Anshori et al. (2021), and Farid et al.
136 (2021). The PCA assessment can map the differences between objects and characters with

137 significant correlation, as reported by Farid et al. (2020). However, this method needs to be
138 combined with machine learning concepts, which require large objects (Dijk et al., 2020). Their
139 combination is expected to further increase the precision in decision-making. The results of this
140 study can serve as a good basis for developing a cultivation assessment based on principal
141 component analysis in the future

142

143 **Materials and Methods**

144

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

149 **Experimental Design and Statistical Analysis**

150 This study explored the irrigated paddy fields of farmers using a 1:2 Legowo planting system.
151 A nested design was then used with replications in different soil texture levels (S), namely sandy
152 (S1), loam (S2), and clay (S3). The second factor was water management (W), which consists of
153 farmers' watering practice (W1) as well as intermittent (W2), dry-wet application (AWD) (W3)
154 and semi puddled (W4) irrigation systems. Each combination treatment was replicated three times
155 to obtain a total of 36 experimental units.

156

157 **Study Procedure**

158 The activities started with soil tillage using a hand tractor to prepare the field for planting. They
159 were then divided into 36 plots of 100 m x 27 m, hence, a total of 1 hectare of land was used.

160 Before planting, the seeds' germination process took three days, after which they were sowed on
161 separate fields and trays. Subsequently, they were transplanted after 11-14 days using a
162 transplanter. The plant maintenance involves replanting based on their conditions as well as the
163 application of fertilizer based on the leaf green color level reading results, which were obtained
164 before tillage and harvesting. The addition of urea fertilizer was carried out with the color chart
165 indicator, after which pest and disease control was performed. Weeding was also conducted using
166 herbicides and physical means, and water was then provided after the treatments.

167

168 **Observation and Data Analysis:**

169 The parameter observed include plant height, the weight of 1000 grains, productivity, number
170 of tillers as well as the number of filled, unfilled, and total grains. They were then analyzed using
171 multivariate evaluation, which consists of correlation and principal component analysis (PCA).

172 The correlation analysis was carried out for all parameters using Rstudio with the corrplot
173 package. Meanwhile, PCA was used for others that correlated significantly to productivity with
174 the STAR 2.0.1 software. All combination treatments were formulated into PC1 and PC2 as the
175 basis for the plot analysis, after which they were plotted in 2 dimensions (Anshori et al., 2021)

176

177 **Conclusion**

178

179 The use of multi-character based on principal component analysis is considered to be effective
180 in evaluating the combination of irrigation methods and soil types. Plant characters, such as
181 height, number of tillers, and weight of 1000 seeds can be used as selection criteria that support
182 the productivity potential of their combination. An intermittent irrigation system is the best

183 method for rice cultivation, specifically in loam and clay soils, where the latter had the best
184 combination. These results can be used as references and recommendations for further studies or
185 practical activities on rice cultivation.

186

187 **References**

- 188 Anshori MF, Purwoko BS, Dewi IS, Ardie SW, Suwarno WB (2021) A new approach to select
189 doubled haploid rice lines under salinity stress using indirect selection index. *Rice Science*. 28:
190 368-378.
- 191 Al-Salim SHF, Al-Edelbi R, Aljbory F, Saleh, MM (2016) Evaluation of the performance of some
192 rice (*Oryza sativa* L.) varieties in two different environments. *Open Access Library Journal*. 3:
193 e2294.
- 194 De Datta SK (1981) *Principles and Practices of Rice Production*. John Wiley & Sons Inc,
195 Singapore.
- 196 Dijk ADJV, Kootstra G, Kruijer W, Ridder DD (2020) Machine learning in plant science and plant
197 breeding. *iScience*. 24: 101890.
- 198 Din M, Rashid M, Fahad M, Ahmad I, Bibi N, Mahboob W, Khan A (2021) Multivariate analysis
199 of rice genotypes for seeding traits' characterization and evaluation. *Pakistan Journal of*
200 *Botany*. 53: 613-619.
- 201 FAO (2011) *The State of The World's Land and Water Resources for Food and Agriculture*
202 *(SOLAW) – Managing Systems at Risk*. Food and Agriculture Organization of the United
203 Nations, Rome and Earthscan, London.
- 204 Farid M, Nasaruddin, Musa Y, Anshori MF, Ridwan I, Hendra J, Gatot S (2020) Genetic
205 parameters and multivariate analysis to determine secondary traits in selecting wheat mutant
206 adaptive on tropical lowlands. *Plant Breeding and Biotechnology*. 8: 368-377.
- 207 Farid M, Nasaruddin, Anshori MF, Musa Y, Iswoyo H, Sakinah AI (2021) Interaction of rice
208 salinity screening in germination and seedling phase through selection index based on principal
209 components. *Chilean Journal of Agricultural Research*. 81: 368-377.
- 210 Firoozi AA, Firoozi AA, Baghini MS (2016) A review of clayey soils. *Asian Journal of Applied*
211 *Sciences*. 4: 1319-1330.
- 212 Hardjowigeno S (1993) *Soil of paddy field*. Post Graduate Program, IPB University, Bogor.
- 213 Herawati A, Mujiyo, Syamsiyah J, Baldan SK, Arifin I (2020) Application of soil amendments as
214 a strategy for water holding capacity in sandy soils. *IOP Conf. Series: Earth and Environmental*
215 *Science*. 724: 012014.
- 216 Jolliffe IT, Cadima J (2016) Principal component analysis: A review and recent developments.
217 *Philosophical Transactions of the Royal Society A*. 374: 20150202.

- 218 Ma X, Feng F, Wei H, Mei H, Xu K, Chen S, Li T, Liang X, Liu H, Luo L (2016) Genome-wide
219 association study for plant height and grain yield in rice under contrasting moisture regimes.
220 *Frontiers in Plant Science*. 7:1801.
- 221 Mamedov AI, Huang C, Aliev FA, Levy GJ (2017) Aggregate stability and water retention near
222 saturation characteristics as affected by soil texture, aggregate size and polyacrylamide
223 application. *Land Degradation & Development*. 28: 543–552.
- 224 Sadimantara GR, Yusuf DN, Febrianti E, Leomo S, Muhidin (2021) The performance of
225 agronomic traits, genetic variability, and correlation studies for yield and its components in
226 some red rice (*Oryza sativa*) promising lines. *Biodiversitas*. 22: 3994-4001.
- 227 Saleh MM, Salem KFM, Elabd AB (2020) Definition of selection criterion using correlation and
228 path coefficient analysis in rice (*Oryza sativa* L.) genotypes. *Bulletin of the National Research
229 Centre*. 44: 143.
- 230 Shetty DK, Acharya UD, Narendra VG, Prajwal PJ (2020) Intelligent system to evaluate the quality
231 of DRC using image processing and then categorize using artificial neural network (ANN).
232 *Indian Journal of Agricultural Research*. 54: 716-723.
- 233 Shi S, Wang E, Li C, Zhou H, Cai M, Cao C, Jiang Y (2021) Comprehensive evaluation of 17
234 qualities of 84 types of rice based on principal component analysis. *Foods*. 10: 2883.
- 235 Wang JX, Sun J, Li CX, Liu HL, Wang JG, Zhao HW, Zou DT (2016) Genetic dissection of the
236 developmental behavior of plant height in rice under different water supply conditions. *Journal
237 of Integrative Agriculture*. 15: 2688–2702.
- 238 Wattoo JI, Khan AS, Ali Z, Babar M, Naeem M, Ullah MA, Hussain N (2010) Study of correlation
239 among yield related traits and path coefficient analysis in rice (*Oryza sativa* L.). *African
240 Journal of Biotechnology*. 9: 7853-7856.
- 241 Zhao H, Mo Z, Lin Q, Pan S, Duan M, Tian H, Wang S, Tang X (2020) Relationships between
242 grain yield and agronomic traits of rice in Southern China. *Chilean Journal of Agricultural
243 Research*. 80: 72-79.
- 244 Zhou L, Liu S, Wu W, Chen D, Zhan X, Zhu A (2016) Dissection of genetic architecture of rice
245 plant height and heading date by multiple-strategy-based association studies. *Scientific
246 Reports*. 6:29718.

247
248
249
250
251
252
253
254
255

256 **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

257 Notes: PC= principal component

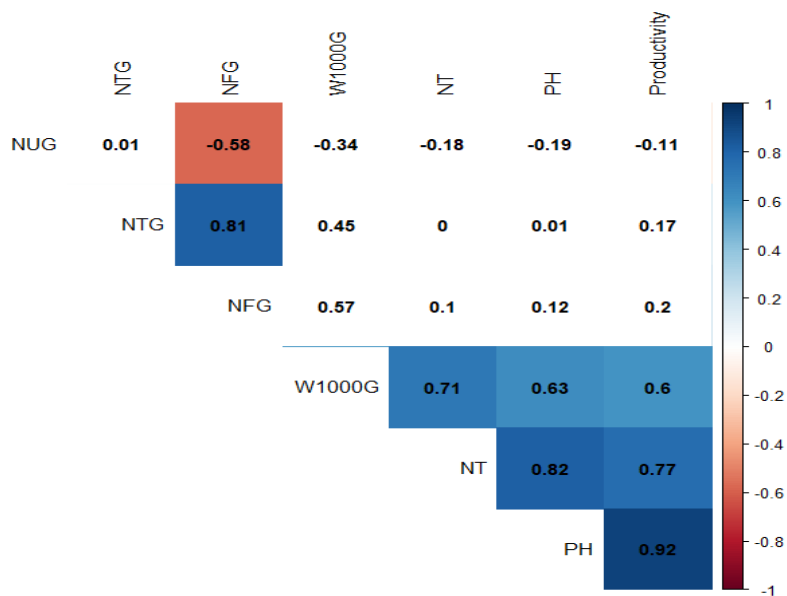
258
259 **Table 2.** Standardization and PCA values on the character of productivity and correlated
260 productivity

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

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

263
264
265
266
267
268
269
270

271
272
273
274
275
276
277
278
279
280
281
282



283 **Fig 1.** Correlation analysis of the character of rice growth (PH= plant height, W1000G = weight of 1000
284 grains, NT= number of tillers, NFG = number of filled grains, NUG = number of unfilled grains, NTG = number of
285 total grains)

286
287
288
289
290
291
292
293
294
295
296
297

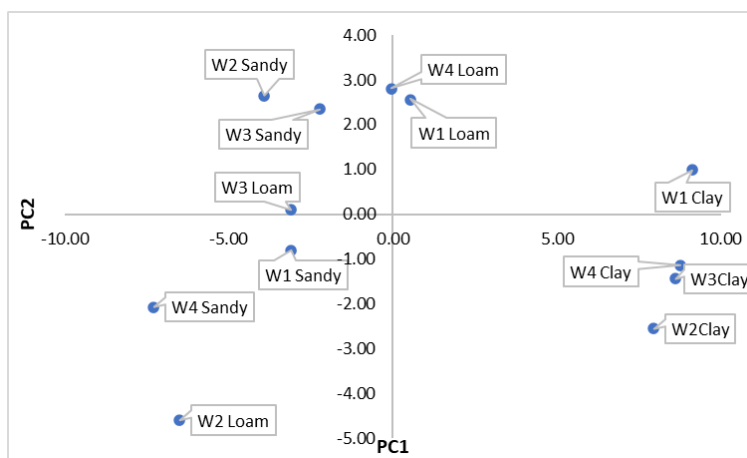
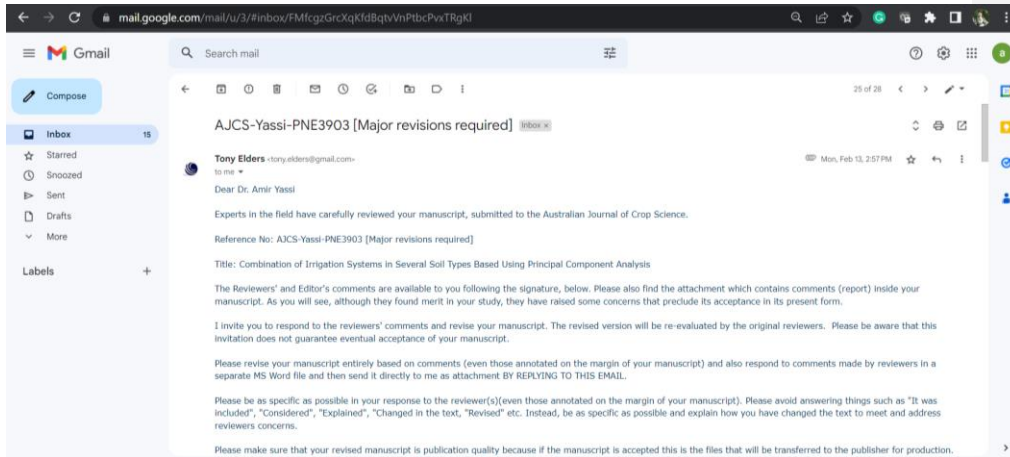


Fig 2. Two-dimensional mapping of PC1 and PC2 against irrigation method (W) and soil type



298

299

300 **Hasil Review dari reviewer**

301

302 **Combination of irrigation systems in several soil types based using principal component**
303 **analysis**

304

305 **Amir Yassi^{1*}, Hari Iswoyo¹, Muhammad Fuad Anshori¹**

306

307 ¹Department of Agronomy, Faculty of Agriculture, Hasanuddin University, Perintis

308 Kemerdekaan Street Km 10, Makassar, South Sulawesi, 90245, Indonesia

309 Street Km 10, Makassar, South Sulawesi, 90245, Indonesia

310 *Corresponding author: amiryassi.22@gmail.com

311

312 **Abstract.** This study aims to determine the effectiveness of Principal Component Analysis in

313 evaluating irrigation systems for different soil types and to obtain information about the best

314 method and combination of factors for rice cultivation. The study was carried out in Soppeng

Commented [A1]: The manuscript needs major English language revision which must be done with help of a native or expert in English language.

Commented [A2R1]: Thank you for your recommendation. We will use proofreading from AJCS

Commented [A3]: Authors should confirm that no part of this study has been published or under publication in any form in any media before publication in AJCS.

Commented [A4R3]: Thank you for your question. We guarantee that it did not published in any media before publication in AJCS

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

326 **Key words:** Irrigation system, Oryza sativa, PCA, Soil texture

327 **Abbreviations** (if any): (PCA_principal component analysis, PC_principal component,
328 PH_plant height, NUG_number of unfilled grains, NT_number of tillers, NTG_number of total
329 grains, W1000G_weight of 1000 grains. ,

330

331 **Introduction**

332 The paddy field is a unique farming system that is often used on a specific commodity,
333 namely rice because it can meet the crops' requirements in terms of soil preparation, water
334 management, and its impact on the environment (FAO, 2011). However, special attention must
335 be paid to inland tillage while managing the field. Hardjowigeno (1993) reported that paddy soil
336 has a pale-colored surface horizon due to the reduction of Fe and Mn from field puddling, which
337 leads to the transfer and deposit of compounds in the soil particle structure and root hairs. It can

Commented [A5]: Change = to _

Commented [A6R5]: Thank you for your recommendation. We have revised according to your suggestion

338 also produce approximately 90% of rice yield, which is decreasing due to the conversion of land
339 for non-agricultural purposes. Rain-fed paddy fields, dryland farms, and tidal land are present in
340 significant areas across regions that have not contributed optimally to the crop's production
341 (FAO, 2011). The management of irrigated areas must consider various aspects to increase and
342 stabilize rice production in Indonesia.

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

349 Soil can be categorized based on their color, which includes red and black as well as their
350 texture, namely sandy, silt, and clay. Furthermore, soil containing more sand, silt, and clay
351 components have macropores, mesopores, and micropores, respectively, with descending
352 degrees of porosity (Firoozi et al., 2016). The type of irrigation and tillage system used on them
353 also depends on their texture. Wang et al. (2016), Mamedov et al. (2017) and Herawati et al.
354 (2020) stated that effective water management can increase the growth and productivity of rice in
355 sandy soil. The use of intermittent irrigation significantly affected vegetative growth, the number
356 of panicles, the weight of 1000 seeds, and yields per hectare. Therefore, the study on the
357 combination of irrigation control and soil type is expected to increase the productivity of paddy.

358 The principal component analysis is an evaluation method that can combine several characters
359 and produce new variants with fewer dimensions. The result of the process still covers most of
360 the existing diversity, hence, it can be used in multivariate analysis. It can also be used for

361 mapping while assessing the cropping process, specifically on interrelated characters. Farid et al.
362 (2021) and Anshori et al. (2021) reported that PCA-based mapping is effective in evaluating rice
363 cultivation on these characters. Din et al. (2021) and Shi et al. (2021) also used the method to
364 evaluate the relationship between genotypes on the morphology and post-harvest quality of rice.
365 Farid et al. (2020) mapped wheat selection characters that are related to the main characteristics
366 of productivity using PCA analysis. These findings indicate that the approach can be used for
367 evaluating the combination of irrigation treatments and soil types in rice cultivation. Therefore,
368 this study aims to determine the effectiveness of PCA analysis in assessing irrigation systems for
369 different soil types as well as to obtain information about the best method and combination of
370 both factors in rice cultivation.

371

372 **Results** *The correlation analysis between agronomy characters*

373 Figure 1 shows the results of the correlation analysis, where the weight of 1000 grains, the
374 number of tillers, and plant height positively correlated to productivity with p-values of 0.60,
375 0.77, and 0.92, respectively. The three parameters also have a significant correlation with each
376 other. Furthermore, the plant height correlated with weight of 1000 grains and the number of
377 tillers with p-values of 0.63 and 0.82, respectively. The grains' weight had a significant
378 correlation with the number of tiller with p-value of 0.71. The number of filled grains also
379 correlated with the unfilled and total grains with p-values of -0.58 and 0.81, respectively.

380

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

382 The principal component analysis results showed that PC1 and PC2 have Proportion of
383 Variance of 0.8078 and 0.1208, respectively. All the characters on PC1 have eigenvectors with

Commented [A7]: Can authors divide this section with some sub-headings.

Commented [A8R7]: Thank you for your suggestions. We have divided the result to some sub-headings

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

390

391 *The clustering graph of PC1 and PC2*

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

396 **Discussion**

397

398 The results of the correlation analysis showed that productivity had a very significant positive
399 correlation with the number of tillers, plant height, and weight of 1000 grains. Several studies also
400 reported the association between the number of tillers and the weight of 1000 grains on
401 productivity (Saleh et al., 2020; Sadimantara et al., 2021). However, the correlation between plant
402 height and productivity has mixed results. Wattoo et al. (2010) and Zhao et al. (2019) reported that
403 the parameters correlate with each other, while Saleh et al. (2020) and Sadimantara et al. (2021)
404 revealed that they do not have a relationship. Al-Salim et al. (2016) stated that plant height has a
405 significant negative correlation with productivity. This finding indicates that its response is highly
406 dependent on the environment and genetics. Wang et al. (2016), Ma et al. (2016), and Zhou et al.

407 (2016) revealed that the height of rice plants is very sensitive to environmental changes,
408 specifically differences in water availability conditions. These results showed that it can serve as
409 a supporting character for productivity along with the number of tillers and weight of 1000 grains
410 during evaluation. Its supportive characteristics can also be combined in the assessment and
411 mapping of irrigation methods combination and soil types in rice production. The data and
412 correlation are often assessed using the principal component analysis.

413 The PCA analysis results showed that PC1's proportion of variance was greater than 0.8. Jolliffe
414 and Cadima (2016), Anshori et al. (2021) revealed that the optimal PC is used when the cumulative
415 proportion is up to 0.8. This indicates that PC1 can represent the combination of the four characters
416 in the analysis. The direction and magnitude of the eigenvectors between variables were also
417 relatively the same. Consequently, PC1 is relevant in PCA analysis, but the use of PC2 as another
418 dimension is also necessary. This was indicated by the eigenvector values between the four
419 characters on PC2, which were not uniform and in the same direction to allow their combination
420 to form a detailed diversity mapping graph, as shown in Figure 2 (Shetty et al., 2020; Farid et al.,
421 2021).

422 Figure 2 shows that the clay soil has a narrow diversity, but it has a large PC1 mean. This
423 indicates that the diversity of irrigation methods has no significant effect on plant growth. Clay
424 soil is characterized by its high water-binding ability (Firoozi et al., 2016) and resistance
425 (Mamedov et al., 2017; Herawati et al., 2020). Consequently, the application of irrigation methods
426 does not affect its potency in supporting the growth of rice plants. The use of limited water,
427 specifically in the intermittent concept also increases its growth potential and productivity
428 compared to excess water. This is illustrated in Figure 2 where W2, W3, and W4 clay are in
429 quadrant four, which is very similar to productivity and plant height. The application of irrigation

430 system in loam and sandy soils showed various responses to rice growth. This is because they have
431 low water binding capacity and resistance compared to clay (Mamedov et al., 2017; Herawati et
432 al., 2020). The diversity of growth in both types of soil depends on the interaction between their
433 ability to bind with water and the time of irrigation for the crop. Based on these findings, the use
434 of clay soil is the right choice for rice cultivation in Indonesia, specifically when combined with
435 intermittent water supply (W2).

436 The results showed that the interaction assessment through principal component analysis was
437 very effective. It can also accommodate several characters with the same direction of diversity.
438 This finding is consistent with the studies carried out by Anshori et al. (2021), and Farid et al.
439 (2021). The PCA assessment can map the differences between objects and characters with
440 significant correlation, as reported by Farid et al. (2020). However, this method needs to be
441 combined with machine learning concepts, which require large objects (Dijk et al., 2020). Their
442 combination is expected to further increase the precision in decision-making. The results of this
443 study can serve as a good basis for developing a cultivation assessment based on principal
444 component analysis in the future

445

446 **Materials and Methods**

447

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

452

453 **Experimental design and statistical analysis**

454 The study explored the irrigated paddy fields of farmers using a 1:2 Legowo planting system.

455 This study was arranged by the nested randomized complete block design, where the replications

456 nesting to different soil texture levels (S), namely sandy (S1), loam (S2), and clay (S3). The main

457 factor was water management (W), which consists of farmers' watering practice (W1) as well as

458 intermittent (W2), dry-wet application (AWD) (W3) and semi puddled (W4) irrigation systems.

459 Each combination treatment was replicated three times to obtain a total of 36 experimental units.

460

461 **Study procedure**

462 The activities started with soil tillage using a hand tractor to prepare the field for planting. They

463 were then divided into 36 plots of 100 m x 27 m, hence, a total of 1 hectare of land was used.

464 Before planting, the seeds' germination process took three days, after which they were sowed on

465 separate fields and trays. Subsequently, they were transplanted after 11-14 days using a

466 transplanter. The plant maintenance involves replanting based on their conditions as well as the

467 application of fertilizer based on the leaf green color level reading results, which were obtained

468 before tillage and harvesting. The addition of urea fertilizer was carried out with the color chart

469 indicator, after which pest and disease control was performed. Weeding was also conducted using

470 herbicides and physical means, and water was then provided after the treatments.

471

472 **Observation and data analysis:**

473 The parameter observed include plant height, the weight of 1000 grains, productivity, number

474 of tillers as well as the number of filled, unfilled, and total grains. They were then analyzed using

475 multivariate evaluation, which consists of correlation and principal component analysis (PCA).

Commented [A9]: What kind of experimental design have you used? How many replication?

Commented [A10R9]: Thank you for your question. The experimental design used in this study is the nested randomized complete block design (line 150) and the replications are three times (line 154)

476 The correlation analysis was carried out for all parameters using Rstudio with the corrplot
477 package. Meanwhile, PCA was used for others that correlated significantly to productivity with
478 the STAR 2.0.1 software. All combination treatments were formulated into PC1 and PC2 as the
479 basis for the plot analysis, after which they were plotted in 2 dimensions (Anshori et al., 2021)

480

481 **Conclusion**

482

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

490 Acknowledgments

491 **References**

- 492 Anshori MF, Purwoko BS, Dewi IS, Ardie SW, Suwarno WB (2021) A new approach to select
493 doubled haploid rice lines under salinity stress using indirect selection index. *Rice Sci.* 28:
494 368-378.
- 495 Al-Salim SHF, Al-Edelbi R, Aljbory F, Saleh, MM (2016) Evaluation of the performance of some
496 rice (*Oryza sativa* L.) varieties in two different environments. *Open Access Lib J.* 3: e2294.
- 497 De Datta SK (1981) *Principles and Practices of Rice Production*. John Wiley & Sons Inc,
498 Singapore.
- 499 Dijk ADJV, Kootstra G, Kruijer W, Ridder DD (2020) Machine learning in plant science and plant
500 breeding. *iScience.* 24: 101890.
- 501 Din M, Rashid M, Fahad M, Ahmad I, Bibi N, Mahboob W, Khan A (2021) Multivariate analysis
502 of rice genotypes for seeding traits' characterization and evaluation. *Pak J Bot.* 53: 613-619.

Commented [A11]: This section should be totally formatted based on journal guidelines and also to avoid extra and missing references compared to text.

Commented [A12R11]: Thank you for your reminder. We have checked the reference with the journal guidelines

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

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

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

512 Firoozi AA, Firoozi AA, Baghini MS (2016) A review of clayey soils. *Asian J Appl Sci.* 4: 1319-
513 1330.

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

516 Herawati A, Mujiyo, Syamsiyah J, Baldan SK, Arifin I (2020) Application of soil amendmets as
517 a strategy for water holding capacity in sandy soils. *IOP Conf Series: Earth and Environ Sci.*
518 724: 012014.

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

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

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

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

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

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

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

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

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

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

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

547

548 **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

549 Notes: PC= principal component

550

551 **Table 2.** Standardization and PCA values on the character of productivity and correlated
 552 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

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

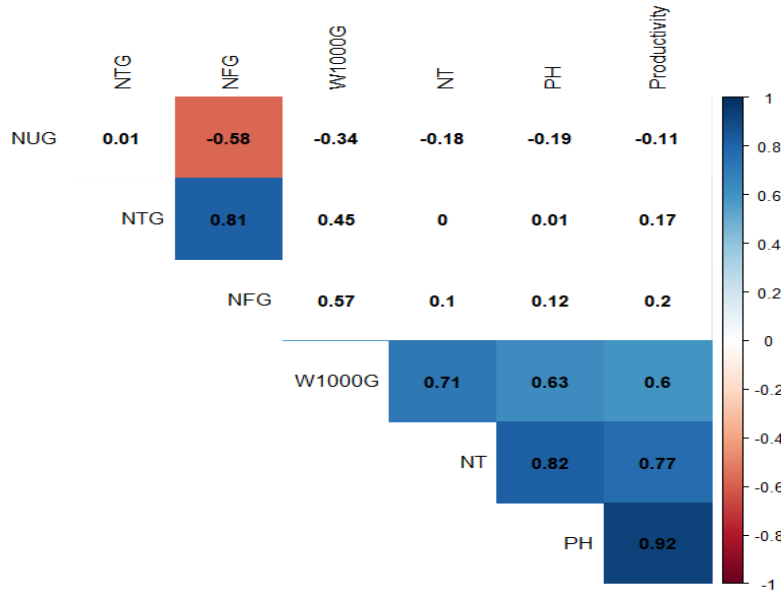
555

556

557

558

559
560
561
562
563
564
565
566
567
568
569
570

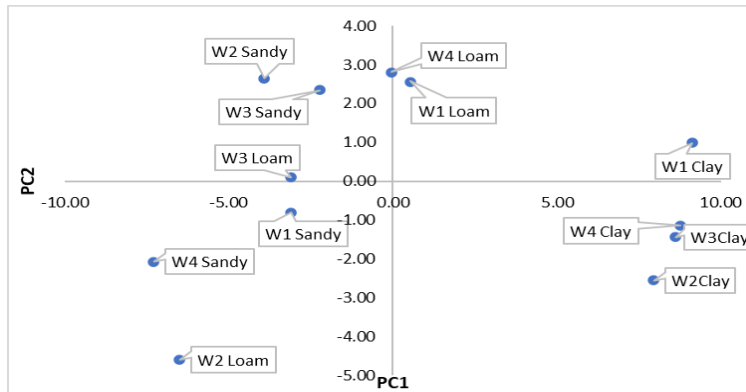


571 **Fig 1.** Correlation analysis among rice agronomy characters (The color sign showed a significant
572 correlation at the 5% error level, PH= plant height, W1000G = weight of 1000 grains, NT= number of tillers, NFG =
573 number of filled grains, NUG = number of unfilled grains, NTG = number of total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

Commented [A13]: Legends should be more informative

Commented [A14R13]: Thank you for your suggestion. we have revised according to your suggestion.

574
575
576
577
578
579
580
581
582



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

Commented [A15]: Legends should be more informative.

Commented [A16R15]: Thank you for your suggestion. we have revised according to your suggestion.

586
587
588
589
590

Table of Response

Thank you for your correction to our manuscript. We would like to response all comments and questions

591

Q1	The manuscript needs major English language revision which must be done with help of a native or expert in English language.
A1	Thank you for your recommendation. We will use proofreading from AJCS recommendation and we accept to pay the English editing fee
Revision	-

592

Q2	Authors should confirm that no part of this study has been published or under publication in any form in any media before publication in AJCS.
A2	Thank you for your question. We guarantee that it did not published in any media before publication in AJCS
Revision	-

593

Q3	Change = to _
A3	Thank you for your recommendation. We have revised according to your suggestion
Revision	(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. (lines 26-28)

594

Q4	Can authors divide this section with some sub-headings.
A4	Thank you for your suggestions. We have divided the result to some sub-headings
Revision	<i>The correlation analysis between agronomy characters (line 73)</i> <i>The principal component analysis of the yield and the supporting characters of the yield (line 82)</i> <i>The mapping graph of PC1 and PC2 (Line 92)</i>

595

Q5	What kind of experimental design have you used? How many replication?
A5	Thank you for your question. The experimental design used in this study is the nested randomized complete block design (line 156) and the replications are three times (line 160)
Revision	the nested randomized complete block design (line 156) treatment was replicated three times (line 160)

Q6	This section should be totally formatted based on journal guidelines and also to avoid extra and missing references compared to text.
A6	Thank you for your reminder. We have checked the reference with the journal guidelines

596

Revision	In reference (lines 193-247)
----------	------------------------------

Q7	Legends should be more informative
A7	Thank you for your suggestion. we have revised according to your suggestion.
Revision	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) (Lines 281-283)

597

Q8	Legends should be more informative.
A8	Thank you for your question. The planting media were consisted of combination of soil, compost or husk charcoal
Revision	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) (lines 294-296)

598

599

600

601

602

603

604

605

606

607

608

609

610

611

612

613

614

615

616

617

618

619

620 **Hasil Perbaikan**

621 **Combination of irrigation systems in several soil types based using principal component**
622 **analysis**

623

624 **Amir Yassi^{1*}, Hari Iswoyo¹, Muhammad Fuad Anshori¹**

625

626 ¹Department of Agronomy, Faculty of Agriculture, Hasanuddin University, Perintis

627 Kemerdekaan Street Km 10, Makassar, South Sulawesi, 90245, Indonesia

628 Street Km 10, Makassar, South Sulawesi, 90245, Indonesia

629 *Corresponding author: amiryassi.22@gmail.com

630

631 **Abstract.** This study aims to determine the effectiveness of Principal Component Analysis in
632 evaluating irrigation systems for different soil types and to obtain information about the best
633 method and combination of factors for rice cultivation. The study was carried out in Soppeng
634 Regency in April-September 2019. A nested design was used with different replication of soil
635 texture levels (S), namely sandy (S1), loam (S2), and clay (S3). The second factor was water
636 management (W), which consists of farmers' watering practice (W1), as well as intermittent
637 (W2), dry-wet application (W3), and semi-puddled (W4) irrigation systems. Each combination
638 treatment was replicated three times to obtain 36 experimental units. Subsequently, observations
639 were carried out on seven yield component parameters, analyzed with multivariate evaluation,
640 correlation, and principal component analysis. The principal component analysis effectively
641 assessed irrigation methods and soil types with an eigenvalue of 0.9286. The intermittent
642 irrigation system was the best method for rice cultivation, specifically in loam and clay soils,

643 where the latter had the best combination. These results are expected to be a basis for future
644 studies or practical activities on the crop's cultivation.

645 **Key words:** Irrigation system, *Oryza sativa*, PCA, Soil texture

646 **Abbreviations** (if any): (PCA_principal component analysis, PC_principal component,
647 PH_plant height, NUG_number of unfilled grains, NT_number of tillers, NTG_number of total
648 grains, W1000G_weight of 1000 grains. ,

649

650 **Introduction**

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

662 Paddy has a high demand for water in the plant's life circle, and this is consistent with De
663 Datta (1981) that it requires approximately 800-1200 mm season⁻¹, or 6-10 mm day⁻¹. This
664 finding is in line with a statement that the irrigation control in paddy is important to increase its
665 yield. The excess puddle system is the most used management method by farmers, but it is

666 wasteful and reduces root development. Consequently, it needs to be changed with a more
667 efficient method, but the effectiveness of irrigation systems still depends on field's texture.

668 Soil can be categorized based on their color, which includes red and black as well as their
669 texture, namely sandy, silt, and clay. Furthermore, soil containing more sand, silt, and clay
670 components have macropores, mesopores, and micropores, respectively, with descending
671 degrees of porosity (Firoozi et al., 2016). The type of irrigation and tillage system used on them
672 also depends on their texture. Wang et al. (2016), Mamedov et al. (2017) and Herawati et al.
673 (2020) stated that effective water management can increase the growth and productivity of rice in
674 sandy soil. The use of intermittent irrigation significantly affected vegetative growth, the number
675 of panicles, the weight of 1000 seeds, and yields per hectare. Therefore, the study on the
676 combination of irrigation control and soil type is expected to increase the productivity of paddy.

677 The principal component analysis is an evaluation method that can combine several characters
678 and produce new variants with fewer dimensions. The result of the process still covers most of
679 the existing diversity, hence, it can be used in multivariate analysis. It can also be used for
680 mapping while assessing the cropping process, specifically on interrelated characters. Farid et al.
681 (2021) and Anshori et al. (2021) reported that PCA-based mapping is effective in evaluating rice
682 cultivation on these characters. Din et al. (2021) and Shi et al. (2021) also used the method to
683 evaluate the relationship between genotypes on the morphology and post-harvest quality of rice.
684 Farid et al. (2020) mapped wheat selection characters that are related to the main characteristics
685 of productivity using PCA analysis. These findings indicate that the approach can be used for
686 evaluating the combination of irrigation treatments and soil types in rice cultivation. Therefore,
687 this study aims to determine the effectiveness of PCA analysis in assessing irrigation systems for

688 different soil types as well as to obtain information about the best method and combination of
689 both factors in rice cultivation.

690

691 **Results**

692

693 *The correlation analysis between agronomy characters*

694 Figure 1 shows the results of the correlation analysis, where the weight of 1000 grains, the
695 number of tillers, and plant height positively correlated to productivity with p-values of 0.60,
696 0.77, and 0.92, respectively. The three parameters also have a significant correlation with each
697 other. Furthermore, the plant height correlated with weight of 1000 grains and the number of
698 tillers with p-values of 0.63 and 0.82, respectively. The grains' weight had a significant
699 correlation with the number of tiller with p-value of 0.71. The number of filled grains also
700 correlated with the unfilled and total grains with p-values of -0.58 and 0.81, respectively.

701

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

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

711

712 *The mapping graph of PC1 and PC2*

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

717 **Discussion**

718

719 The results of the correlation analysis showed that productivity had a very significant positive
720 correlation with the number of tillers, plant height, and weight of 1000 grains. Several studies also
721 reported the association between the number of tillers and the weight of 1000 grains on
722 productivity (Saleh et al., 2020; Sadimantara et al., 2021). However, the correlation between plant
723 height and productivity has mixed results. Wattoo et al. (2010) and Zhao et al. (2019) reported that
724 the parameters correlate with each other, while Saleh et al. (2020) and Sadimantara et al. (2021)
725 revealed that they do not have a relationship. Al-Salim et al. (2016) stated that plant height has a
726 significant negative correlation with productivity. This finding indicates that its response is highly
727 dependent on the environment and genetics. Wang et al. (2016), Ma et al. (2016), and Zhou et al.
728 (2016) revealed that the height of rice plants is very sensitive to environmental changes,
729 specifically differences in water availability conditions. These results showed that it can serve as
730 a supporting character for productivity along with the number of tillers and weight of 1000 grains
731 during evaluation. Its supportive characteristics can also be combined in the assessment and
732 mapping of irrigation methods combination and soil types in rice production. The data and
733 correlation are often assessed using the principal component analysis.

734 The PCA analysis results showed that PC1's proportion of variance was greater than 0.8. Jolliffe
735 and Cadima (2016), Anshori et al. (2021) revealed that the optimal PC is used when the cumulative
736 proportion is up to 0.8. This indicates that PC1 can represent the combination of the four characters
737 in the analysis. The direction and magnitude of the eigenvectors between variables were also
738 relatively the same. Consequently, PC1 is relevant in PCA analysis, but the use of PC2 as another
739 dimension is also necessary. This was indicated by the eigenvector values between the four
740 characters on PC2, which were not uniform and in the same direction to allow their combination
741 to form a detailed diversity mapping graph, as shown in Figure 2 (Shetty et al., 2020; Farid et al.,
742 2021).

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

757 The results showed that the interaction assessment through principal component analysis was
758 very effective. It can also accommodate several characters with the same direction of diversity.
759 This finding is consistent with the studies carried out by Anshori et al. (2021), and Farid et al.
760 (2021). The PCA assessment can map the differences between objects and characters with
761 significant correlation, as reported by Farid et al. (2020). However, this method needs to be
762 combined with machine learning concepts, which require large objects (Dijk et al., 2020). Their
763 combination is expected to further increase the precision in decision-making. The results of this
764 study can serve as a good basis for developing a cultivation assessment based on principal
765 component analysis in the future

766

767 **Materials and Methods**

768

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

773

774 **Experimental design and statistical analysis**

775 The study explored the irrigated paddy fields of farmers using a 1:2 Legowo planting system.
776 This study was arranged by the nested randomized complete block design, where the replications
777 nesting to different soil texture levels (S), namely sandy (S1), loam (S2), and clay (S3). The main
778 factor was water management (W), which consists of farmers' watering practice (W1) as well as

779 intermittent (W2), dry-wet application (AWD) (W3) and semi puddled (W4) irrigation systems.

780 Each combination treatment was replicated three times to obtain a total of 36 experimental units.

781

782 **Study procedure**

783 The activities started with soil tillage using a hand tractor to prepare the field for planting. They

784 were then divided into 36 plots of 100 m x 27 m, hence, a total of 1 hectare of land was used.

785 Before planting, the seeds' germination process took three days, after which they were sowed on

786 separate fields and trays. Subsequently, they were transplanted after 11-14 days using a

787 transplanter. The plant maintenance involves replanting based on their conditions as well as the

788 application of fertilizer based on the leaf green color level reading results, which were obtained

789 before tillage and harvesting. The addition of urea fertilizer was carried out with the color chart

790 indicator, after which pest and disease control was performed. Weeding was also conducted using

791 herbicides and physical means, and water was then provided after the treatments.

792

793 **Observation and data analysis:**

794 The parameter observed include plant height, the weight of 1000 grains, productivity, number

795 of tillers as well as the number of filled, unfilled, and total grains. They were then analyzed using

796 multivariate evaluation, which consists of correlation and principal component analysis (PCA).

797 The correlation analysis was carried out for all parameters using Rstudio with the corplot

798 package. Meanwhile, PCA was used for others that correlated significantly to productivity with

799 the STAR 2.0.1 software. All combination treatments were formulated into PC1 and PC2 as the

800 basis for the plot analysis, after which they were plotted in 2 dimensions (Anshori et al., 2021)

801

802 **Conclusion**

803

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

811

812 **References**

- 813 Anshori MF, Purwoko BS, Dewi IS, Ardie SW, Suwarno WB (2021) A new approach to select
814 doubled haploid rice lines under salinity stress using indirect selection index. *Rice Sci.* 28:
815 368-378.
- 816 Al-Salim SHF, Al-Edelbi R, Aljbory F, Saleh, MM (2016) Evaluation of the performance of some
817 rice (*Oryza sativa* L.) varieties in two different environments. *Open Access Lib J.* 3: e2294.
- 818 De Datta SK (1981) *Principles and Practices of Rice Production*. John Wiley & Sons Inc,
819 Singapore. 317.
- 820 Dijk ADJV, Kootstra G, Kruijer W, Ridder DD (2020) Machine learning in plant science and plant
821 breeding. *iScience.* 24: 101890.
- 822 Din M, Rashid M, Fahad M, Ahmad I, Bibi N, Mahboob W, Khan A (2021) Multivariate analysis
823 of rice genotypes for seeding traits' characterization and evaluation. *Pak J Bot.* 53: 613-619.
- 824 FAO (2011) *The State of The World's Land and Water Resources for Food and Agriculture*
825 *(SOLAW) – Managing Systems at Risk*. Food and Agriculture Organization of the United
826 Nations, Rome and Earthscan, London. 14-15.
- 827 Farid M, Nasaruddin, Musa Y, Anshori MF, Ridwan I, Hendra J, Gatot S (2020) Genetic
828 parameters and multivariate analysis to determine secondary traits in selecting wheat mutant
829 adaptive on tropical lowlands. *Plant Breed Biotech.* 8: 368-377.
- 830 Farid M, Nasaruddin, Anshori MF, Musa Y, Iswoyo H, Sakinah AI (2021) Interaction of rice
831 salinity screening in germination and seedling phase through selection index based on principal
832 components. *Chil J Agric Res.* 81: 368-377.

833 Firoozi AA, Firoozi AA, Baghini MS (2016) A review of clayey soils. *Asian J Appl Sci.* 4: 1319-
834 1330.

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

837 Herawati A, Mujiyo, Syamsiyah J, Baldan SK, Arifin I (2020) Application of soil amendments as
838 a strategy for water holding capacity in sandy soils. *IOP Conf Series: Earth and Environ Sci.*
839 724: 012014.

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

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

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

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

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

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

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

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

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

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

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

868

869

870

871

872

873

874

875 **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
Eigen Values	3.2313	0.4833	0.2141	0.0713

876 Notes: PC= principal component

877

878 **Table 2.** Standardization and PCA values on the character of productivity and correlated
879 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

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

882

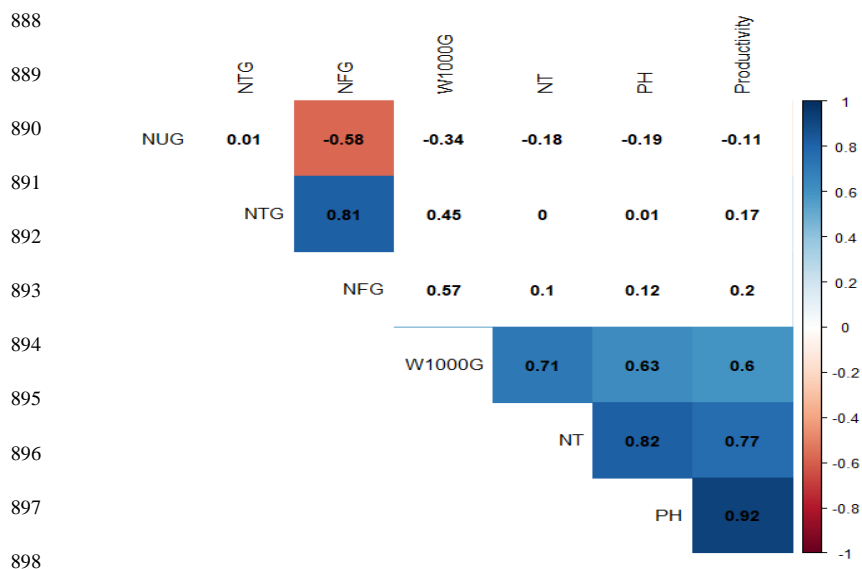
883

884

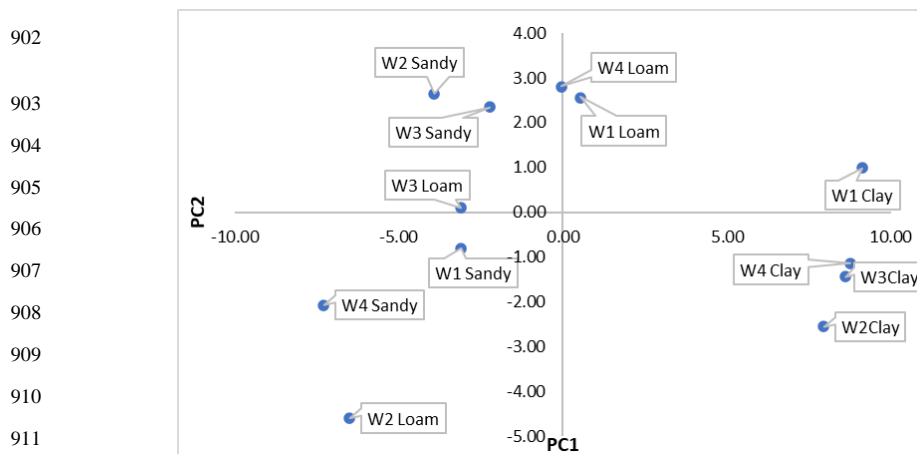
885

886

887



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



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

915 **Acceptance proof**

916

917

