YYÜ TAR BİL DERG
(YYU J AGR SCI)
2017, 27(4): 473-480

Geliş Tarihi (Received): 07.06.2017
Kabul Tarihi (Accepted): 19.10.2017
doi: 10.29133/yyutbd.319500

Araştırma Makalesi/*Research Article (Original Paper)*

# Selecting Best Rice Varieties under Drought Stress and Non-Stress Conditions Using Selection Indices

**Mehdi RAHIMI[1*], Mehdi RAMEZANI[2], Mojtaba KORDROSTAMI[3]**

[1]Department of Biotechnology, Institute of Science and High Technology and Environmental Sciences, Graduate University of Advanced Technology, Kerman, Iran
[2]Young Researchers and Elite Club, Ahvaz Branch, Islamic Azad University, Ahvaz, Iran
[3]Rice Research Institute of Iran, Agricultural Research, Education and Extension Organization (AREEO), Rasht, Iran
e-mail: mehdi83ra@yahoo.com; Phone: 00989173079874

**Abstract:** Grain yield and most of the traits that have economic importance in plants, herited as quantity and using direct selection method have not large progress. So, one of the most effective method's indirect selections as improve grain yield with a trait effective on it, is using of selection index. In this research, 42 Iranian local and improved rice varieties were evaluated in randomized complete block design with three replications under two separate conditions, normal irrigation and drought stress during 2014 and 12 traits were measured. Estimating 10 different selection indices based on optimum and base indices in both conditions indicated that selecting for grain yield per plant, 1000-grain weight, number of filled grain per panicle, canopy temperature and number of panicles per plant in non-stress condition and grain yield per plant, 1000-grain weight and number of total spikelet per panicle in stress condition by using their path direct coefficients as economic weights would be a suitable selection criterion for improving of population. Results distinguished that selected varieties based on optimum and base indices in both conditions are almost similar. Thus, optimum and base indices in non-stress condition are proposed as a criterion for selecting high-yield vrieties to use in stress conditions.

**Keywords:** Grain yield, Path analysis, Rice (*Oryza sativa* L.), Selection indices, Stress condition

## Seleksiyon Endekslerini Kullanılarak Kuraklık Stresi ve Stres Olmayan Koşulları Altında En İyi Çeltik Çeşitlerinin Seçimi

**Özet:** Tane verimi ve bitkilerde kantitatif kalıtımlı ve doğrudan seçme yöntemini kullanılan ekonomik önemi olan özelliklerin çoğunun büyük bir gelişme göstermediği saptanmıştır. Dolayısıyla, etkili bir özelliğe sahip tane verimi artırmak için en etkin yöntemlerden dolaylı seçimlerinden biri, seleksiyon endeksini kullanılmaktadır. Bu araştırmada 42 adet İran yerel ve gelişmiş pirinç çeşidi, 2014 yılı boyunca normal sulama ve kuraklık stresi olmak üzere iki ayrı koşulda üç tekerrürlü olarak tesadüfi tam blok deneme deseninde incelenmiş ve 12 özellik değerlendirilmiştir. Her iki koşulda optimum ve baz indekslerine dayanan 10 farklı seçim indeksinin tahmin edilmesi, ekonomik ağırlık olarak doğrudan path katsayılarının kullanılmasıyla bitki başına tane verimi, 1000 tane ağırlığı, başakta dolu tane sayısı, kanopi sıcaklığı ve stres olmayan koşullar altında bitki başına başak sayısı, bitki başına tane verimi ve stres koşullarında 1000 tane ağırlığı ve her bir başakta başakçık sayısının populasyonun iyileştirilmesi için uygun bir seçim kriteri olacağını işaret etmektedir. Sonuçlar, her iki koşulda da optimum ve baz indekslerine dayalı seçilen çeşitlerin neredeyse benzer olduğunu göstermiştir. Böylece, stres olmayan koşullarındaki optimum ve baz indeksleri, stres koşullarında yüksek verimli çeşitlerin seçimi için bir kriter olarak önerilmektedir.

**Anahtar kelimeler:** Tahıl verimi, Path analizi, Pirinç (*Oryza sativa* L.), Seleksiyon endeksleri, Stres koşulu

## Indroduction

Rice (*Oryza sativa* L.) is the most important food crop, as over half of the world, population consumes rice as their principal source of nourishment (Ramakrishnan et al. 2006). Also, yield of the crop's is a very complex trait, and direct selection is not much effective on it. Therefore, the most desirable approach to improve traits such as grain yield is simultaneous selection based on related traits (Bos and Caligari 2008).

Since the economic value of a plant depends on its different trait values, plant breeders should consider simultaneous selection for two or more traits to maximize the economic value of a plant. The use of a selection index was originally proposed by H. F. Smith (1936) argued that since genotypic worth could not be directly evaluated, it might be best estimated by a linear function of observable phenotypic values. The maximum response to index selection will be achieved if the correlation between genetic worth and the index is maximized (Baker 1986). Plant breeders have had more success using the index selection for increasing expected responses than by using direct selection of different traits in different plants (Xie et al. 1997; Jannink et al. 2000; Monirifar 2010; Eshghi et al. 2011). Moreover, it has been used for increasing expected genetic advance in recurrent selection programs (Smith et al. 1981; Weyhrich et al. 1998).

Gravois and McNew (1993) showed that selecting for increased yield via selection for either panicle weight or panicle number alone was ineffective in the field. In contrast, they indicated that selection for both increased panicle weight and panicle number to increase yield was estimated to be 91% as effective as selecting for yield directly. In another research, Rabiei et al. (2004) studied selection indices for the rice grain shape. They indicated that the selection index based on the path analysis results was an effective selection criterion. Furthermore, Sabouri et al. (2008) compared selection indices for rice yield improvement and showed that selection for grain weight, number of panicles per plant and panicle length by using their phenotypic and/or genotypic direct effects (path coefficient) as economic weights were served as an effective selection criterion for using either the optimum or base index. Furthermore, Fazlalipour et al. (2008) showed that selection for biomass (BM), harvest index (HI) and number of grains per panicle (GP) using genotypic path coefficients and their heritability as economic values based on optimum and base indices was a suitable selection criterion for improving population in rice.

The objectives of this study were to obtain a suitable selection index based on relationships among important agronomic traits in two irrigation conditions and using a suitable selection index to select the high-yielding varieties in rice.

## Materials and Methods

A total of 42 Iranian local and improved rice varieties including Ahlami-Tarom, Binam, Hassan-Saraee, Hassani, Domzard, Gharib, Ghasroddashti, Nemat, Bijar, Khazar, Sepidrood, Sang.e.Tarom, Shiroodi, Anbarboo, Mehr, Neda, Hashemi, Abjibooji, Amol, Bahar, Toka-51, Champa-Boodar, Hassnjoo, Dorfak, Dasht, Dom.Sefid, Sahel, Salari, Sangjoo, Shafagh, Saleh, Sadri, Tarom-Amiri, Tarom-Molaee, Tarom-Mahalli, Ali Kazemi, Kadus, Gohar, Gil-1, Gil-3, Dom Siah and Mohammadi were used to evaluate best selection indices in the rice under sever drought stress conditions. The experiment was carried out under two different conditions (normal irrigation and drought stress) based on the randomized complete block design with three replications in the Lahijan, Iran, during 2014. Under the stress condition, irrigation of research field was completely stopped in 30 days after transplanting to the end of the growth period. Soil moisture was measured by Gypsum blocks that placed in the field. The soil moisture was observed every two days to ensure that drought stress had been doing well. Mean resistance of the Gypsum blocks was measured at three stages of plant growth (mid-tillering, flowering and maturity) and based on the calibration diagram of Gypsum block was calculated volumetric soil moisture. Meteorological data (climate data) and soil characteristics are shown at Tables 1 and 2.

Table 1. Some physical and chemical properties of farm soil

| Sample depth (cm) | Measurement characteristics | | | | | | |
|---|---|---|---|---|---|---|---|
| | Electrical conductivity ($dS.m^{-1}$) | Organic carbon (%) | Total nitrogen (%) | Absorbable phosphorus (ppm) | Absorbable potassium (ppm) | pH of Saturated soil | Soil texture |
| 0-30 | 2.37 | 2.65 | 0.25 | 15.83 | 195.2 | 6.7 | Clay Silty |

Table 2. Meteorological information of the six crop season of 2014 year

| Month | Mean temperature (°c) | Temperature (°c) | | Rainfall per month (mm) |
|---|---|---|---|---|
| | | Min | Max | |
| April | 14 | -0.2 | 25.4 | 12 |
| May | 22.2 | 12.4 | 32.5 | 10.9 |
| June | 24.8 | 15.6 | 34.4 | 3.2 |
| July | 26.4 | 19.8 | 34.5 | 10.2 |
| August | 27.6 | 19.6 | 37.5 | 15.6 |
| September | 23.9 | 16.8 | 35.4 | 54.3 |

In both conditions, each variety was planted in a 2 m × 2 m plot. In each plot had three rows. Single plants were transplanted at 30 days after sowing with distance of 25 cm between plants and 30 cm between rows. The studied traits were days to flowering (DF, days from sowing to 50% flowering), days to maturity (DM, days from sowing to 85% maturity), plant height (PH, cm), panicle length (PL, cm), number of panicle per plant (NPP), number of total spikelet per panicle (NTSP), number of filled grain per panicle (NFGP), number of empty spikelet per panicle (NESP), canopy temperature (CT, ºC), spikelet fertility (SF, percent), 1000-grain weight (GW, gr), grain yield (GY, g/plant). All studied traits were measured on 10 plants per plot. The studied traits were recorded based on the standard evaluation system for rice ((InternationalRiceResearchInstitute 2002).

Stepwise regression analysis and sequential path analysis was done using statistical software of SPSS ver. 19.0 (SPSS 2010), to describe the relationships among the traits and to determine the traits which effective on the yield. The direct and indirect effect of each trait on the yield based on genotypic correlations were revealed by path analysis and was done by the Amos Software ver. 19.0 (Arbuckle 2010).

Phenotypic and genotypic variance matrix and genotypic correlation coefficients were calculated by the suggested equation by Acquaah (2007) based on the expected value of mean squares (MS) and mean products (MP) of treatment and experimental error of RCB design Also, broad-sense heritability for each trait was calculated as $\frac{\sigma_{gi}^2}{\sigma_{pi}^2}$, where $\sigma_{gi}^2$ and $\sigma_{pi}^2$ are the genotypic and phenotypic variances of the ith trait, respectively that suggested by Acquaah (2007).

In this study to evaluate the selection strategies for maximizing rice yield, different selection indices were calculated based on optimum and base indices and different economic values (Table 3), as described by H. F. Smith (1936); Hazel (1943); Brim et al. (1959); Baker (1986)*4, 9, 19, 20*) used to present a suitable selection index. Furthermore, several different scales were used to evaluation indices.

$$R_{HI} = \frac{\sigma_{HI}}{\sqrt{\sigma_I^2 \times \sigma_H^2}} = \frac{\sigma_I}{\sigma_H} = \sqrt{\frac{b'Pb}{a'Ga}} \quad (1)$$

$$\Delta H = kR_{HI}\sigma_H \quad (2)$$

$$\Delta = \frac{kGb}{\sqrt{b'Pb}} \quad (3)$$

$$RE = \frac{R_I}{R_A} = \frac{r_{G(A)I}}{h_{(A)}} \quad (4)$$

$$r_{G(A)I} = \frac{b'g}{\sqrt{\sigma_{G(A)}^2 \times b'Pb}} \quad (5)$$

$$R_I = kr_{G(A)I}\sigma_{G(A)} \quad (6)$$

$$R_A = kh_{(A)}\sigma_{G(A)} \quad (7)$$

Where $\sigma_I^2$, $\sigma_H^2$, $\sigma_{HI}$, k, $\sigma_H$, $r_{HI}$, RI, RA, h(A), $r_{G(A)I}$ and $\sigma_{G(A)}^2$ are variance of index, variance of breeding worth, covariance between index and breeding worth, the standardized selection differential (which in the present study with use of 10% selection intensity it was equal to 1.76), the standard deviation of breeding value, the correlation coefficients between the breeding values and index, the response to selection for yield based on selection index, response to selection caused via selection of itself and the square root of the heritability of trait A, the correlation between the genotypic values for trait A and index values and the genotypic standard deviation for trait A. The SAS software ver. 9.2 (SASInstitute 2010) was used for phenotypic and genotypic variance-covariance matrix and selection index analysis.

Table 3. Economic weight and trait combinations to Construction of the selection indices in normal and stress conditions

| Condition | Trait[a] | Relative economic weights for 10 selection indices | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Normal condition | DF | 1 | 1 | 0.97 | 0.97 | -0.21 | -0.21 | 0 | 0 | 0.5 | 0.5 |
| | DM | 1 | 1 | 0.95 | 0.95 | -0.20 | -0.20 | 0 | 0 | 0 | 0 |
| | NPP | 1 | 1 | 0.99 | 0.99 | 0.53 | 0.53 | 0.64 | 0.64 | 1 | 1 |
| | CT | 1 | 1 | 0.93 | 0.93 | 0.19 | 0.19 | 0.06 | 0.06 | 1 | 1 |
| | NFGP | 1 | 1 | 0.99 | 0.99 | 0.51 | 0.51 | 0.62 | 0.62 | 1 | 1 |
| | SF | 1 | 1 | 0.96 | 0.96 | 0.37 | 0.37 | 0 | 0 | 0.5 | 0.5 |
| | GW | 1 | 1 | 0.98 | 0.98 | 0.21 | 0.21 | 0.54 | 0.54 | 1 | 1 |
| | GY | 1 | 0 | 0 | 0.84 | 0 | 1 | 0 | 1 | 0 | 1 |
| | NTSP | 1 | 1 | 0.99 | 0.99 | 0.36 | 0.36 | 0 | 0 | 0.5 | 0.5 |
| | NESP | 1 | 1 | 0.97 | 0.97 | -0.11 | -0.11 | 0 | 0 | 0 | 0 |
| | PH | 1 | 1 | 0.99 | 0.99 | 0.04 | 0.04 | 0 | 0 | 0 | 0 |
| | PL | 1 | 1 | 0.99 | 0.99 | -0.04 | -0.04 | 0 | 0 | 0 | 0 |
| Stress condition | DF | 1 | 1 | 0.98 | 0.98 | 0.02 | 0.02 | 0 | 0 | 0 | 0 |
| | DM | 1 | 1 | 0.94 | 0.94 | 0.00 | 0.00 | 0 | 0 | 0 | 0 |
| | NPP | 1 | 1 | 0.99 | 0.99 | 0.49 | 0.49 | 0.50 | 0.50 | 1 | 1 |
| | CT | 1 | 1 | 0.96 | 0.96 | 0.11 | 0.11 | 0 | 0 | 0.5 | 0.5 |
| | NFGP | 1 | 1 | 0.98 | 0.98 | 0.35 | 0.35 | 0 | 0 | 0.5 | 0.5 |
| | SF | 1 | 1 | 0.98 | 0.98 | -0.17 | -0.17 | 0 | 0 | 0 | 0 |
| | GW | 1 | 1 | 0.98 | 0.98 | 0.11 | 0.11 | 0.34 | 0.34 | 1 | 1 |
| | GY | 1 | 0 | 0 | 0.86 | 0 | 1 | 0 | 1 | 0 | 1 |
| | NTSP | 1 | 1 | 0.99 | 0.99 | 0.48 | 0.48 | 0.50 | 0.50 | 1 | 1 |
| | NESP | 1 | 1 | 0.98 | 0.98 | 0.36 | 0.36 | 0 | 0 | 0 | 0 |
| | PH | 1 | 1 | 0.99 | 0.99 | 0.05 | 0.05 | 0 | 0 | 0 | 0 |
| | PL | 1 | 1 | 0.99 | 0.99 | 0.03 | 0.03 | 0 | 0 | 0 | 0 |

[a] Trait abbreviations are: DF, 50% flowering; DM, 85% maturity; NPP, number of panicle per plant; CT, canopy temperature; NFGP, number of filled grain per panicle; SF, spikelet fertility; GW, 1000-grain weight; GY, grain yield; NTSP, number of total spikelet per panicle; NESP, number of empty spikelet per panicle; PH, plant height; PL, panicle length.

## Results and Discussion

Combined analysis of variance (Table 4) indicated significant genotypes and genotype × environment interaction variance ($P < 0.01$) and showed the influence of changes in environments on the grain yield of the evaluated genotypes. Mean comparison of genotypes showed that in both conditions, the highest values for most traits had been belonging to AliKazemi, Dorfak, Kadus, Sangjoo, Tarom-Mahalli varieties in non-stress condition. However, AliKazemi, Dorfak, Kadus, Sangjoo, Tarom-Mahalli varieties had the highest values for most traits in stress condition. Positive and highly significant correlations of grain yield were found with NPP (0.54 and 0.50), NFGP (0.52 and 0.35) and NTSP (0.38 and 0.49) in both conditions, respectively. Grain yield was negatively and significantly correlated with days to maturity (-0.20) and days to flowering (-0.22) in non-stress condition while there was no significant correlation between these traits in stress condition. The results also showed the highest positive correlation between NFGP and NTSP (0.80) and DM and DF (0.73) in non-stress condition. In contrast, the highest positive correlation was observed between NTSP and NESP (0.82) and NTSP and NFGP (0.65) in stress conditions (data not shown).

The stepwise regression analysis for GY in both conditions indicated that NPP, NFGP, GW and CT in non-stress condition and NPP, NTSP and GW in stress condition as first-order variables were added to model and accounted for 88 and 51% of GY variation, respectively (data not shown). Path coefficient analysis showed the direct effects of NPP, NFGP, GW and CT on GY were 0.64, 0.62, 0.54 and 0.06 in non-stress condition, respectively. In contrast, the direct effects of NPP, NTSP and GW on GY were 0.50, 0.34 and 0.50 in stress condition, respectively.

In this study, 10 selection indices were calculated based on two methods (optimum and base) and combinations of 12 traits with various economic weights in both conditions to evaluate selection strategies to maximize grain yield (Table 5 and 6). In both conditions, the indexes 1 and 2 had an economic weight of one for all traits except

GY that was zero in index 2. Broad sense heritability was used for obtaining economic weights for the indices 3 and 4 except GY in index 3 was zero. The index 5 and 6 were obtained by phenotypic correlation between grain yield and other trait which the correlation of GY in index 5 was zero. The economic weight for obtaining the indices 7 and 8 were phenotypic direct effects of the first-order predictors. In the index 9 and 10, the economic weights for the first-order predictors, second-order predictors and other traits were 1, 0.5 and 0, respectively.

Table 3 shows correlation coefficient between genotypic worth and each index, the relative efficiency of indices and expected genetic advance in each trait on the basis of the optimum and base indices in non-stress condition. Comparisons of the estimated optimum and base indices in non-stress condition indicated that the selection indices 6, 7 and 8 had the highest relative efficiency (E), genotypic correlations (RG) and response to selection (RHI). The economic weights for the indices 7 and 8 were phenotypic direct effects for the first-predictor variables in grain yield path analysis, while the economic weight in the selection index 6 was phenotypic correlation (Table 5). Since few traits (4 or 5 traits) were used for developing the indices 7 and 8, these indices are preferred to other indices. Moreover, among the indices 7 and 8, the index 8 is preferred to others, because only grain yield per plant, 1000-grain weight, number of filled grains per panicle, canopy temperature and number of panicles per plant were used for developing this index.

The results of optimum and base indices in stress condition are shown in Table 6. The indexes 6 and 8 showed the highest relative efficiency (E), genotypic correlations (RG) and response to selection (RHI) among the 10 optimum and base indices. Moreover, the index 8 in stress condition had the highest genetic advance (Δ) for grain yield based on optimum and base indices. Finally, based on comparison of optimum and base indices in both conditions, the selection index 8 selected as the best selection index to improvement the grain yield in rice genotypes.

Selection index 8 were used to select high-yielding rice varieties in both non-stress and stress conditions based on optimum and base indices at 10% selection intensities. The results showed that the selecting varieties (AliKazemi, Dorfak, Kadus, Sangjoo, Tarom-Mahalli) had the highest values for most traits in both non-stress and stress conditions and the varieties Hassani, Sepidrood and DomSiah had the lowest values for most traits in both non-stress and stress conditions. By compassion of results distinguished that selected varieties based on optimum and base indices in both conditions are almost similar. Thus, optimum and base indices in non-stress condition are proposed as a criterion for selecting high-yield varieties to use in stress conditions. The results indicated that several genes control the studied traits. Sabouri et al. (2008) are reported similar results. Besides, the correlations' analysis showed that increasing of such traits would enhance the grain yield.

Table 5. Estimated correlation coefficients between genotypic worth and each index, and expected genetic advance in each trait with 10% selection intensity (*k*=1.76) according to the base and optimum indices in normal condition

| | Index[a] | Trait[b] | | | | | | | | | | | | HΔ | $R_G$ | $R_{HI}$ | E |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | DF | DM | NPP | CT | NFGP | SF | GW | GY | NTSP | NESP | PH | PL | | | | |
| Base | 1 | 0.85 | 1.22 | 0.92 | 0.18 | 25.56 | 0 | -1.69 | 5.51 | 38.49 | 12.93 | 7.17 | 0.93 | 92.74 | 0.49 | 0.996 | 0.53 |
| | 2 | 1.22 | 1.53 | 0.34 | 0.15 | 24.71 | -0.01 | -2.00 | 4.37 | 38.72 | 14.01 | 7.61 | 1.02 | 87.57 | 0.39 | 0.998 | 0.42 |
| | 3 | 1.16 | 1.49 | 0.36 | 0.15 | 24.80 | -0.01 | -2.00 | 4.40 | 38.72 | 13.92 | 7.68 | 1.03 | 86.59 | 0.39 | 0.999 | 0.42 |
| | 4 | 0.85 | 1.23 | 0.85 | 0.18 | 25.54 | 0 | -1.74 | 5.38 | 38.55 | 13.02 | 7.31 | 0.95 | 90.87 | 0.47 | 0.997 | 0.52 |
| | 5 | -2.57 | -1.30 | 1.43 | 0.24 | 33.06 | 0.06 | -2.34 | 6.94 | 36.96 | 3.90 | 0.09 | -0.33 | 31.46 | 0.61 | 0.996 | 0.67 |
| | 6 | -2.72 | -1.53 | 2.51 | 0.28 | 31.17 | 0.06 | -1.38 | 8.68 | 33.55 | 2.38 | 0.04 | -0.34 | 39.99 | 0.77 | 0.984 | 0.83 |
| | 7 | -1.66 | -0.63 | 1.58 | 0.19 | 33.14 | 0.09 | -1.18 | 8.14 | 31.38 | -1.77 | -1.26 | -0.40 | 21.20 | 0.72 | 0.991 | 0.78 |
| | 8 | -2.03 | -1.09 | 2.86 | 0.24 | 29.18 | 0.08 | -0.21 | 9.67 | 27.10 | -2.08 | -0.89 | -0.38 | 31.14 | 0.85 | 0.972 | 0.93 |
| | 9 | 0.17 | 0.67 | 0.78 | 0.18 | 31.44 | 0.04 | -1.80 | 6.49 | 39.11 | 7.67 | 2.36 | 0.22 | 53.32 | 0.57 | 0.997 | 0.62 |
| | 10 | -0.31 | 0.25 | 1.59 | 0.21 | 30.87 | 0.04 | -1.27 | 7.78 | 37.13 | 6.26 | 2.04 | 0.14 | 60.98 | 0.69 | 0.990 | 0.75 |
| Optimum | 1 | 0.82 | 1.20 | 0.91 | 0.18 | 25.63 | 0 | -1.73 | 5.37 | 38.64 | 13.01 | 7.21 | 0.93 | 92.18 | 0.47 | 0.997 | 0.52 |
| | 2 | 1.19 | 1.50 | 0.34 | 0.15 | 24.77 | -0.01 | -2.02 | 4.33 | 38.74 | 13.99 | 7.63 | 1.03 | 87.32 | 0.38 | 0.999 | 0.42 |
| | 3 | 1.14 | 1.46 | 0.36 | 0.15 | 24.85 | -0.01 | -2.03 | 4.36 | 38.74 | 13.90 | 7.71 | 1.04 | 86.34 | 0.38 | 0.999 | 0.42 |
| | 4 | 0.82 | 1.21 | 0.85 | 0.18 | 25.60 | 0 | -1.78 | 5.24 | 38.68 | 13.08 | 7.35 | 0.95 | 90.38 | 0.46 | 0.998 | 0.50 |
| | 5 | -2.57 | -1.28 | 1.44 | 0.24 | 33.02 | 0.06 | -2.35 | 6.84 | 37.17 | 4.12 | 0.09 | -0.36 | 31.25 | 0.60 | 0.997 | 0.66 |
| | 6 | -2.78 | -1.55 | 2.55 | 0.28 | 31.59 | 0.06 | -1.46 | 8.47 | 34.38 | 2.74 | 0.04 | -0.40 | 39.00 | 0.75 | 0.991 | 0.81 |
| | 7 | -1.70 | -0.64 | 1.61 | 0.19 | 33.24 | 0.09 | -1.20 | 8.00 | 31.84 | -1.44 | -1.28 | -0.44 | 20.89 | 0.71 | 0.994 | 0.77 |
| | 8 | -2.14 | -1.14 | 2.95 | 0.25 | 30.03 | 0.08 | -0.29 | 9.52 | 28.35 | -1.74 | -0.94 | -0.45 | 29.78 | 0.84 | 0.984 | 0.92 |
| | 9 | 0.14 | 0.66 | 0.78 | 0.18 | 31.41 | 0.04 | -1.82 | 6.38 | 39.27 | 7.84 | 2.37 | 0.20 | 53.04 | 0.56 | 0.998 | 0.61 |
| | 10 | -0.35 | 0.25 | 1.60 | 0.21 | 31.07 | 0.04 | -1.33 | 7.57 | 37.67 | 6.56 | 2.08 | 0.11 | 60.05 | 0.67 | 0.994 | 0.73 |

[a] Each index has been calculated based on the optimum index using the economic weights presented in Table 1.

[b] Trait abbreviations are Trait abbreviations are: DF, 50% flowering; DM, 85% maturity; NPP, number of panicle per plant; CT, canopy temperature; NFGP, number of filled grain per panicle; SF, spikelet fertility; GW, 1000-grain weight; GY, grain yield; NTSP, number of total spikelet per panicle; NESP, number of empty spikelet per panicle; PH, plant height; PL, panicle length.

Table 4. Combined analysis of variances for the studied traits of rice $F_5$ families

| **S.O.V.**[a] | **df** | **Traits**[b] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | DF | DM | NPP | CT | NFGP | SF | GW | GY | NTSP | NESP | PH | PL |
| En. | 1 | 1627.33** | 954.14** | 2243.53** | 183.77** | 30837.71** | 0.13** | 354.79** | 20387.89** | 31218.98** | 3.77** | 2014.17** | 696.47** |
| R./En. | 4 | 60.54 | 22.53 | 41.72 | 0.85 | 9.63 | 0.0002 | 0.02 | 274.068 | 7.27 | 0.15 | 60.86 | 24.69 |
| Gen. | 41 | 6264.83** | 89.54** | 155.96** | 2.99** | 1569.15** | 0.03** | 117.84** | 342.88** | 4423.05** | 1556.34** | 1710.61** | 81.47** |
| Gen.×En. | 41 | 3175.49** | 42.25** | 29.55** | 2.76** | 115.29** | 0.02** | 3.38** | 27.37** | 298.89** | 504.46** | 60.39** | 7.46** |
| Er. | 164 | 0.91 | 1.13 | 0.27 | 0.07 | 1.13 | 0.0001 | 0.66 | 6.58 | 1.02 | 1.59 | 0.15 | 0.13 |
| CV (%) | | 1.47 | 1.27 | 2.46 | 0.83 | 1.29 | 1.75 | 3.25 | 7.35 | 0.76 | 2.48 | 0.33 | 1.27 |

[a] Sources of variation abbreviations are: En., Environment; R., Replication; Gen., Genotypes; Er. Error.

[b] Trait abbreviations are: DF, 50% flowering; DM, 85% maturity; NPP, number of panicle per plant; CT, canopy temperature; NFGP, number of filled grain per panicle; SF, spikelet fertility; GW, 1000-grain weight; GY, grain yield; NTSP, number of total spikelet per panicle; NESP, number of empty spikelet per panicle; PH, plant height; PL, panicle length.

[ns,] * and ** : Non-significant and significant at 5% and 1% probability levels, respectively.

Some researcher (Rabiei et al. 2004; Sabouri et al. 2008) are found significant and positive relationships between grain yield and NFGP, DM, NPP and NTEP. The direct and indirect effect values from path analysis (Figure 1 and 2) showed that NPP and GW in the first step and NFGP in second level had the highest positive effect on GY in both conditions. However, these traits had the medium and positive correlation with grain yield in simple correlation study. Furthermore, indirect effects of these traits via other traits were very low and negative or positive. Therefore, this trait due to low indirect effects through other traits can be used as a good criterion for selecting high-yielding varieties. Fazlalipour et al. (2008) were obtained the similar results. Therefore, in this study the best selection criteria determined by using the path analysis and then based on this selection index identified the best variety in both conditions.

Among the 10 base and optimum indices in both conditions, the indexes number 6, 7 and 9 showed the highest relative efficiency (RE), response to selection (RI) and genotypic correlation with grain yield (GY). Moreover, the index 8 had the highest genetic advance (Δ) for grain yield. In addition, the indices 5, 6 and 9 indcated high positive genetic advance for important traits (Tables 5 and 6). However, among all the evaluated indices, the index 8 calculated by optimum and base indices in both conditions were the best indices. The economic weight for index 8 was direct effects of the first-order variables. Also, other researchers such as Gravois and McNew (1993); Rabiei et al. (2004); Fazlalipour et al. (2008) obtained similar results and expressed the use of the first-order variables in the path model can help the breeders to improve high-yielding genotypes by using these indices.

Table 6. Estimated correlation coefficients between genotypic worth and each index, and expected genetic advance in each trait with 10% selection intensity (k=1.76) according to the base and optimum indices in stress condition

| | Index[a] | Trait[b] | | | | | | | | | | | | ΔH | $R_G$ | $R_{HI}$ | E |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | DF | DM | NPP | CT | NFGP | SF | GW | GY | NTSP | NESP | PH | PL | | | | |
| Base | 1 | 2.51 | 0.88 | 2.38 | 0.28 | 15.76 | -0.09 | -1.28 | 7.82 | 43.66 | 27.90 | 6.39 | 0.78 | 107.60 | 0.62 | 0.997 | 0.66 |
| | 2 | 2.67 | 0.94 | 1.96 | 0.27 | 15.77 | -0.09 | -1.48 | 6.80 | 44.01 | 28.25 | 6.71 | 0.82 | 100.08 | 0.54 | 0.999 | 0.58 |
| | 3 | 2.64 | 0.91 | 1.96 | 0.27 | 15.72 | -0.09 | -1.48 | 6.80 | 44.01 | 28.29 | 6.77 | 0.83 | 99.04 | 0.54 | 0.999 | 0.58 |
| | 4 | 2.50 | 0.86 | 2.33 | 0.28 | 15.73 | -0.09 | -1.31 | 7.71 | 43.73 | 28.00 | 6.49 | 0.80 | 105.47 | 0.61 | 0.998 | 0.65 |
| | 5 | 1.38 | 0.05 | 2.34 | 0.24 | 16.93 | -0.09 | -2.12 | 6.93 | 46.56 | 29.64 | 0.29 | -0.01 | 39.91 | 0.55 | 0.999 | 0.59 |
| | 6 | 1.19 | 0.05 | 3.17 | 0.26 | 16.43 | -0.08 | -1.55 | 9.06 | 44.53 | 28.10 | 0.57 | 0.03 | 48.33 | 0.71 | 0.993 | 0.77 |
| | 7 | 1.22 | 0.06 | 2.88 | 0.21 | 16.56 | -0.09 | -1.53 | 7.52 | 45.91 | 29.35 | -0.46 | -0.08 | 24.06 | 0.59 | 0.999 | 0.64 |
| | 8 | 0.95 | 0.05 | 3.84 | 0.24 | 15.36 | -0.08 | -0.80 | 10.17 | 41.56 | 26.20 | 0.15 | 0.00 | 33.65 | 0.80 | 0.986 | 0.86 |
| | 9 | 1.83 | 0.42 | 2.32 | 0.23 | 18.12 | -0.08 | -1.37 | 7.38 | 45.76 | 27.64 | 2.21 | 0.24 | 64.11 | 0.58 | 0.999 | 0.63 |
| | 10 | 1.65 | 0.38 | 2.88 | 0.25 | 17.65 | -0.07 | -1.08 | 8.74 | 44.49 | 26.84 | 2.18 | 0.24 | 72.54 | 0.69 | 0.995 | 0.74 |
| Optimum | 1 | 2.50 | 0.86 | 2.36 | 0.28 | 15.73 | -0.09 | -1.31 | 7.62 | 43.84 | 28.09 | 6.40 | 0.79 | 107.05 | 0.60 | 0.998 | 0.65 |
| | 2 | 2.66 | 0.92 | 1.98 | 0.27 | 15.78 | -0.09 | -1.52 | 6.75 | 44.02 | 28.27 | 6.75 | 0.82 | 99.85 | 0.53 | 0.999 | 0.57 |
| | 3 | 2.63 | 0.89 | 1.89 | 0.27 | 15.73 | -0.09 | -1.42 | 6.75 | 44.11 | 28.31 | 6.71 | 0.83 | 98.82 | 0.53 | 0.999 | 0.57 |
| | 4 | 2.49 | 0.84 | 2.22 | 0.28 | 15.70 | -0.09 | -1.25 | 7.52 | 43.97 | 28.16 | 6.41 | 0.80 | 105.00 | 0.59 | 0.998 | 0.64 |
| | 5 | 1.38 | 0.06 | 3.03 | 0.24 | 16.96 | -0.09 | -2.82 | 6.92 | 45.90 | 29.63 | 0.98 | -0.01 | 39.82 | 0.54 | 0.999 | 0.59 |
| | 6 | 1.19 | 0.05 | 3.66 | 0.26 | 16.43 | -0.09 | -2.12 | 8.73 | 44.53 | 28.58 | 1.07 | 0.04 | 47.73 | 0.69 | 0.994 | 0.74 |
| | 7 | 1.27 | 0.11 | 12.50 | 0.23 | 17.80 | -0.10 | -11.08 | 8.05 | 39.73 | 31.36 | 8.93 | -0.08 | 22.43 | 0.63 | 0.933 | 0.68 |
| | 8 | 0.95 | 0.08 | 10.56 | 0.26 | 16.03 | -0.08 | -7.49 | 10.15 | 37.48 | 28.00 | 6.69 | 0.01 | 31.70 | 0.80 | 0.955 | 0.86 |
| | 9 | 1.87 | 0.46 | 9.87 | 0.25 | 18.93 | -0.08 | -8.90 | 7.65 | 40.37 | 28.90 | 9.77 | 0.26 | 61.22 | 0.60 | 0.956 | 0.65 |
| | 10 | 1.67 | 0.41 | 9.48 | 0.26 | 18.25 | -0.08 | -7.69 | 8.78 | 39.85 | 28.12 | 8.78 | 0.26 | 69.47 | 0.69 | 0.963 | 0.74 |

[a] Each index has been calculated based on the optimum index using the economic weights presented in Table 1.
[b] Trait abbreviations are Trait abbreviations are: DF, 50% flowering; DM, 85% maturity; NPP, number of panicle per plant; CT, canopy temperature; NFGP, number of filled grain per panicle; SF, spikelet fertility; GW, 1000-grain weight; GY, grain yield; NTSP, number of total spikelet per panicle; NESP, number of empty spikelet per panicle; PH, plant height; PL, panicle length.

## Conclusions

The selected varieties by using selection indices had the highest values for most traits in both non-stress and stress conditions and were similar. Therefore, optimum and base indices in non-stress condition are proposed as a criterion for selecting high-yield varieties to use in stress conditions. These results showed that the selecting varieties (AliKazemi, Dorfak, Kadus, Sangjoo and Tarom-Mahalli) had the highest values for most traits in both non-stress and stress conditions and the varieties Hassani, Sepidrood and DomSiah had the lowest values for most traits in both non-stress and stress conditions.

## References


Acquaah G (2007). Principles of Plant Genetics and Breeding, Wiley-Blackwell, Malden, USA.

Arbuckle JL (2010). IBM SPSS Amos 19 user's guide. *Amos Development Corporation. Crawfordville FL*, 654pp.

Baker RJ (1986). Selection Indices in Plant Breeding, CRC Press, Inc., 218pp.
Bos I, Caligari P (2008). Selection Methods in Plant Breeding, (2nd Edition). Springer Science + Business Media B.V., 445pp.
Brim CA, Cockerham HW, Clark C (1959). Multiple selection criteria in soybeans. Agronomy J. 51(1): 42.
Eshghi R, Ojaghi J, Salayeva S (2011). Genetic gain through selection indices in hulless barley. International Journal of Agriculture and Biology 13(2): 191-197.
Fazlalipour M, Rabiei B, Samizadeh Lahiji H, Rahim Soroush H (2008). Multi-trait selection for screening elite genotypes of an $F_2$ rice population. Journal of Sciences and Technology of Agriculture and Natural Resources 11(42): 41-53 In Farsi with Abstract in English.
Gravois KA, McNew RW (1993). Genetic relationships among and selection for rice yield and yield components. Crop science 33(2): 249-252.
Hazel LN (1943). The genetic basis for constructing selection indexes. Genetics 28(6): 476-490.
InternationalRiceResearchInstitute (2002). Standard Evaluation System for Rice. International Rice Research Institute, Manila, Philippines, 56pp.
Jannink JL, Orf JH, Jordan NR, Shaw RG (2000). Index selection for weed suppressive ability in soybean. Crop science 40(4): 1087-1094.
Monirifar H (2010). Evaluation of Selection Indices for Alfalfa (*Medicago sativa* L.). Notulae Scientia Biologicae 2(1): 84-87.
Rabiei B, Valizadeh M, Ghareyazie B, Moghaddam M (2004). Evaluation of selection indices for improving rice grain shape. Field Crops Research 89(2-3): 359-367.
Ramakrishnan SH, Anandakumar CR, Saravanan S, Malini N (2006). Association analysis of some yield traits in rice (*Oryza sativa* L.). Journal of Applied Sciences Research 2(7): 402-404.
Sabouri H, Rabiei B, Fazlalipour M (2008). Use of selection indices based on multivariate analysis for improving grain yield in rice. Rice Science 15(4): 303-310.
SASInstitute I (2010). Base SAS 9.2 Procedures Guide: Statistical Procedures, third edition. Cary, NC: SAS Institute Inc., 7886pp.
Smith HF (1936). A discriminant function for plant selection. Annals of Human Genetics 7(3): 240-250.
Smith OS, Hallauer AR, Russell WA (1981). Use of index selection in recurrent selection programs in maize. Euphytica 30(3): 611-618.
SPSS I (2010). IBM SPSS statistics 19 Core System User's Guide. USA: SPSS Inc., an IBM Company Headquarters, 444pp.
Weyhrich RA, Lamkey KR, Hallauer AR (1998). Responses to seven methods of recurrent selection in the BS11 maize population. Crop science 38(2): 308-321.
Xie C, Xu S, Mosjidis JA (1997). Multistage selection indices for maximum genetic gain and economic efficiency in red clover. Euphytica 98(1): 75-82.