ISSN: 2287-688X

Annals of
Plant Sciences

Volume 11, Issue 04 (2022) pp. 5013-5032

Research Article

Character Association and Stress Indices Analysis for Yield Components in Sub 1 QTL Introgressed Backcross Lines of Rice (*Oryza Sativa* L.)

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Abstract

The present study was carried out by utilizing two cosmopolitan rice varieties ADT 43 and Improved White Ponni (IWP) along with donor for submergence tolerance FR13A. The backcross generations of two cross combinations (cross 1 (ADT 43 x FR 13A) and cross 2 (IWP x FR 13A)) were raised in nursery beds and transplanted to main field at the water level of 40 cm at Agricultural College and Research Institute, Madurai in Randomized Block Design under submerged condition. Character association of the yield attributing traits revealed that the traits number of tillers per plant, number of productive tillers per plant, number of filled grains per panicle, total number of grains per panicle and spikelet fertility have to be given priority during selection to increase grain yield under submergence stress as they were significantly and positively correlated with single plant yield and inter correlated among themselves. Path Coefficient analysis revealed that the traits number of productive tillers per plant and number of filled grains per panicle are the major yield contributing traits to be given importance during selection under submergence condition as they had high direct effect on grain yield and also exhibit high indirect effect on single plant yield through total number of grains per panicle.

Keywords: *Rice, QTLs, Submergence, Association, Segregating population, Yield.*

Introduction

Flooding is undoubtedly the third most vital constraint for achieving high productivity, after heat and drought that is affecting crop production. The seasonal and unseasonal crop damage due to the occurrence of severe flooding amounts to billions of dollars in yield losses annually. At the moment, one of the most flood-threatened crops is rice. About 30% (700 million) of people living in abject poverty (*i.e.*, daily income less than 1$) in Asian countries reside in flood-prone rice cultivating regions of South Asia, with Nepal, Bangladesh, and India accounting for half of the above-stated figure. Bailey-serres *et al.* 2010 stated that out of 16.1 million hectares of rice-growing areas in India, 5.2 million are occasionally affected by flood. According to Wassmann *et al.* 2009, these deltas provided up to 70% of total rice cultivation areas in these countries, and continuous flooding will greatly threaten their food security. In fact, over 35% of rice-growing areas, mostly in Africa and Asia, where food insecurity is predominant are prone to flooding (Bailey-serres *et al.* 2012). Excessive flooding portends a major risk to human livelihood and it is also a major contributor to the vulnerability and poverty in marginalized rural populations. It was projected that flood-prone coastal region will experience an increase in rainfall pattern, especially in tropical and subtropical regions (Sarkar *et al.* 2014). The increase in flooding regime associated with climate change and the necessity to step up the current

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DOI: http://dx.doi.org/10.21746/aps.2022.11.4.2

agricultural yield potential by 70% remains a great challenge to feed the human population, which is expected to reach over nine billion by 2050 (Godfray *et al.* 2010). Therefore, the development of resilient crops to combat flooding is required to nip this problem in bud. The distribution and abundance of plant species adapted to flood-prone environments are determined by the evolutionary pressure based on the selection of advantageous traits of plants under the affected areas. Submergence or waterlogging adaptabilities are heightened by the development of either anatomic or metabolic traits. These traits represent the source of genetic diversity, which can be exploited by plant breeding. Similarly, it acts in synergy to prove submergence tolerance in plants. The major objective of the international community is to increase the current agricultural production to catch up with the anticipated growth in population. Based on this background, it is essential to adopt germplasm and develop better abiotic resistant cultivars that can withstand flooding. Achieving this objective was reflected in the development of submergence-tolerant rice varieties that survive floods, and were subsequently deployed to farmers' fields in flood-prone rice-cultivating areas. This was manifested through the International Rice Research Institute's (IRRI) initiation of a robust submergence tolerance breeding programme of modern rice varieties that were developed through marker-assisted selection from local landraces.

Based on the available literature, FR13A is the most recognized submergence tolerant landrace and has been widely used as a donor parent for tolerance in breeding programs. Similarly, it has been widely used for quantitative trait locus (QTL) association mapping and subsequent map-based cloning of the *SUB1* gene.Hence, the purpose of this research programme is to identify the traits which are having direct correlation with yield coupled with submergence tolerance in rice, once the traits are identified thenthese traits are to be given priority during the selection programme for improving yield under submergence condition in rice.

Materials and Methods

The experimental material consists of two parents along with backcross populations in two cross combinations (cross 1 (ADT 43 x FR 13A) and cross 2 (IWP x FR 13A)) and were raised in nursery beds during July, 2016. Twenty-five days old seedlings were transplanted to main field at Agricultural College and Research Institute, Madurai in Randomized Block Design under submerged condition of 40 cm depth of water with two replications, adopting a spacing of 20cm between rows and 15cm between plants. The water level was monitored periodically and maintained at 40 cm depth for 14 days. After 14 days of complete submergence, the field was de-submerged and survival of the plants was scored after 14 days of recovery. The scoring was done as per the standard evaluation system of rice (SES) developed by IRRI (1988) based on the per cent plant survival (PPS) as shown in Table 1. Ten plants each in P_1, P_2 and 150 plants each in BC_1 and BC_2were maintained for each cross per replication for the study. The phenotypic scoring was done at 21 days after de-submergence of water as per the standard evaluation system of rice (SES) developed by IRRI for submergence. Observations were recorded on biometrical traits in all the available plants in P_1, P_2, BC_1 and BC_2 generations.

Table 1.Scale developed by Hille-Ris Lambers *et al.* (1983)

Score	Symptoms	Tolerance
1	Erect, little or no elongation	HT- Highly tolerant
3	Erect, green, elongated	T - Tolerant
5	Elongated and bent at middle	MT- Moderately tolerant
7	Elongated and lodged flat	S - Susceptible
9	Elongated and apparently dead	HS – Highly susceptible

The scores 1 and 3 are grouped as tolerant and scores 5, 7 and 9 are grouped under susceptible category for phenotypic scoring. The observations were also recorded on 10 biometrical traits in all the available plants in P_1, P_2, B_1 and B_2 generations, to reveal character association.

Statistical Analysis

The correlation coefficient was calculated as per Goulden (1952) and coefficient of correlation was partitioned into path coefficient using the technique outlined by Dewey and Lu (1959). The direct and indirect effects were classified based on the scale given by Lenka and Misra (1973).

Results

Correlation coefficient analysis:

Cross 1 (ADT43 x FR13A) and Cross 2 (IWP x FR13A)

The phenotypic correlation for BC_1in cross 1 for grain yield was positive and highly significant for the traits *viz*., number of filled grains (0.706), number of productive tillers (0.640), number of tillers (0.597), total number of grains (0.531) and spikelet fertility (0.468). It had positive association with plant height (0.054) in B_1 generation under submergence (Table 2). In BC_2 generation, the single plant yield expressed positive and significant association with number of filled grains (0.747), total number of grains (0.692), number of tillers (0.538), number of productive tillers (0.553) and spikelet fertility (0.439). It also expressed positive correlation with days to flowering in cross 1. (Table 3)

The BC_1 of cross 2 had a positive and significant relationship with the traits namely number of filled grains (0.857), total number of grains (0.839), spikelet fertility (0.484), number of productive tillers (0.483), number of tillers (0.365) and plant height (0.272) for grain yield under submergence(Table 4). The relationship of single plant yield with number of filled grains (0.809), total number of grains (0.745), number of productive tillers (0.539), number of tillers (0.420) and spikelet fertility (0.445) was significantly positive in BC_2 cross 2 whereas the remaining traits namely days to flowering and plant height are positive. (Table 5)

The correlation coefficient of days to flowering with panicle length (0.048) and total number of grains (0.056) was positive and rest are negatively non-significant (Table 2). However, positive association was noticed with plant height, panicle length, number of filled grains, total number of grains and spikelet fertility in cross 1 of BC_2 generation. (Table 3)

In cross 2, the inter correlation of days to flowering with number of productive tillers (0.470) and number of tillers (0.414) was positive and highly significant in BC_1. It had positive association with plant height (0.022) and spikelet fertility (0.146) (Table 4). In BC_2, this trait exhibited positive and significant relationship with number of productive tillers (0.230) alone. Plant height, panicle length, number of tillers and 1000 grain weight registered positive association with days to flowering. (Table 5)

In BC_1, the association of plant height with number of tillers (0.346) and number of productive tillers (0.291) was positively significant however panicle length (0.222) exhibited positive association with plant height in cross 1. In BC_2, plant height recorded positive and significant correlation with panicle length (0.363) and negatively significant association (-0.240) with number of productive tillers in cross 1 under submergence. It had a positive correlation

with number of filled grains, total number of grains and spikelet fertility.

In BC_1, the plant height had a positive and significant relationship with number of tillers (0.458) and number of productive tillers (0.296). Whereas it had positive association with panicle length (0.050), number of filled grains (0.151) and total number of grains (0.175). It had positive association with number of filled grains (0.170), spikelet fertility (0.161), total number of grains (0.132) and panicle length (0.115) in BC_2 cross 2.

Panicle length expressed negative but non-significant association with all the traits studied for cross 1 in the first back cross generation, whereas all the traits expressed negatively non-significant association with panicle length except 1000 grain weight (0.014) in BC_2, where it was positive association with panicle length under submergence. In BC_2, the panicle length had positive association with 1000 grain weight (0.233) and negative association with number of productive tillers (-0.329) respectively. It had a non-significantly positive association with total number of grains. (Fig. 1 and Fig. 2)

Number of tillers had a positively significant association with number of productive tillers (0.928) and positive with 1000 grain weight (0.080) in BC_1 of cross 1 (Table 2). In BC_2,number of tillers per plant trait had positively significant correlation with number of productive tillers (0.895) alone (Table 3). Number of tillers per plant had positive and highly significant association with number of productive tillers in BC_1 (0.804) of cross 2 (Table 4). In $BC_2$of cross 2, number of tillers had significantly positive association with number of productive tillers (0.781) and positive association with spikelet fertility and 1000 grain weight (Table 5). Positive and significant relationship was exhibited in BC_1 generation by total number of grains (0.794) and spikelet fertility (0.621) with number of filled grains per panicle in cross 1. (Fig. 1 and Fig. 2)

The traits total number of grains (0.986) and spikelet fertility (0.539) was positively significant and positive association with 1000 grain weight in cross 2 BC_1 generation. Number of filled grains had a positively significant relationship with total number of grains (0.949) and spikelet fertility (0.482) in BC_2 generation. In BC_1, total number of grains per panicle expressed positive relationship with spikelet fertility (0.024) alone. However, in BC_2 generation under submergence the cross 1 showed positive and significant correlation with spikelet fertility alone.

Total number of grains in cross 2 possessed positive and significant inter correlation with spikelet fertility (0.400), while 1000 grain weight showed positive (0.016) association in BC_1 (Table 4). The association of total number of grains with spikelet fertility (0.187) and 1000 grain weight (0.005) was positive in BC_2 generation (Table 5).

The trait spikelet fertility percentage showed positive but non-significant association with 1000 grain weight alone (0.172) in the first back cross of cross 1 (Table 2). In BC_2, positive but non-significant correlation exhibited by 1000 grain weight alone (0.194) with this trait under submergence (Table 3). The BC_1 generation of cross 2, positive association was exhibited with 1000 grain weight (0.015) alone by this trait.

Table 2. Phenotypic Correlation coefficients between different traits in BC_1 generation under submergence – Cross 1

Traits	Days to flowering	Plant height	Panicle length	Number of tillers	Number of productive tillers	Number of filled grains	Total number of grains	Spikelet fertility	1000 grain weight	Single plant yield
Days to flowering	**1.000**	-0.145	0.048	-0.120	-0.123	-0.150	0.056	-0.320**	-0.164	-0.224
Plant height		**1.000**	0.222	0.346**	0.291*	-0.198	-0.202	-0.061	-0.181	0.054
Panicle length			**1.000**	-0.085	-0.171	-0.075	-0.015	-0.101	-0.040	-0.171
Number of tillers				**1.000**	0.928**	-0.087	-0.037	-0.117	0.080	0.597**
Number of productive tillers					**1.000**	-0.079	-0.107	-0.006	-0.056	0.640**
Number of filled grains						**1.000**	0.794**	0.621**	0.006	0.706**
Total number of grains							**1.000**	0.024	-0.147	0.531**
Spikelet fertility								**1.000**	0.172	0.468**
1000 grain weight									**1.000**	-0.035

*Significant at 5 % level
**Significance at 1 % level

Table 3. Phenotypic Correlation coefficients between different traits in BC_2 generation under submergence – Cross 1

Traits	Days to flowering	Plant height	Panicle length	Number of tillers	Number of productive tillers	Number of filled grains	Total number of grains	Spikelet fertility	1000 grain weight	Single plant yield
Days to flowering	**1.000**	0.202	0.052	-0.004	-0.010	0.176	0.180	0.045	-0.202	0.137
Plant height		**1.000**	0.363**	-0.129	-0.240*	0.065	0.018	0.134	-0.035	-0.086
Panicle length			**1.000**	-0.195	-0.174	-0.053	-0.064	0.000	0.014	-0.123
Number of tillers				**1.000**	0.895**	-0.061	-0.103	0.051	-0.102	0.538**
Number of productive tillers					**1.000**	-0.129	-0.132	-0.070	-0.093	0.553**
Number of filled grains						**1.000**	0.939**	0.574**	0.026	0.747**
Total number of grains							**1.000**	0.262*	-0.052	0.692**
Spikelet fertility								**1.000**	0.194	0.439**
1000 grain weight									**1.000**	-0.014

*Significant at 5 % level
**Significance at 1 % level

Table 4. Phenotypic Correlation coefficients between different traits in BC_1 generation under submergence – Cross 2

Traits	Days to flowering	Plant height	Panicle length	Number of tillers	Number of productive tillers	Number of filled grains	Total number of grains	Spikelet fertility	1000 grain weight	Single plant yield
Days to flowering	**1.000**	0.022	-0.365**	0.414**	0.470**	-0.100	-0.137	0.146	-0.125	0.163
Plant height		**1.000**	0.050	0.458**	0.296*	0.151	0.175	-0.053	-0.005	0.272*
Panicle length			**1.000**	-0.073	-0.173	-0.116	-0.109	-0.055	-0.268	-0.193
Number of tillers				**1.000**	0.804**	-0.056	-0.066	-0.016	-0.053	0.365**

Number of productive tillers					**1.000**	-0.025	-0.036	0.022	-0.099	0.483**
Number of filled grains						**1.000**	0.986**	0.539**	0.018	0.857**
Total number of grains							**1.000**	0.400**	0.016	0.839**
Spikelet fertility								**1.000**	0.015	0.483**
1000 grain weight									**1.000**	-0.031

*Significant at 5 % level
**Significance at 1 % level

Table 5. Phenotypic Correlation coefficients between different traits in BC_2 generation under submergence – Cross 2

Traits	Days to flowering	Plant height	Panicle length	Number of tillers	Number of productive tillers	Number of filled grains	Total number of grains	Spikelet fertility	1000 grain weight	Single plant yield
Days to flowering	**1.000**	0.102	0.089	0.175	0.230*	-0.164	-0.087	-0.275*	0.069	0.023
Plant height		**1.000**	0.115	-0.327**	-0.205	0.170	0.132	0.161	-0.203	0.037
Panicle length			**1.000**	-0.088	-0.329**	-0.022	0.016	-0.116	0.233*	-0.203
Number of tillers				**1.000**	0.781**	-0.041	-0.049	0.003	0.042	0.420**
Number of productive tillers					**1.000**	-0.048	-0.084	0.074	-0.003	0.539**
Number of filled grains						**1.000**	0.949**	0.482**	-0.052	0.809**
Total number of grains							**1.000**	0.187	0.005	0.745**
Spikelet fertility								**1.000**	-0.215	0.445**
1000 grain									**1.000**	-0.057

weight										

*Significant at 5 % level
**Significance at 1 % level

Table 6. Direct and indirect effects of different traits on single plant yield in BC_1 generation under submergence – Cross 1

Traits	Days to flowering	Plant height	Panicle length	Number of tillers	Number of productive tillers	Number of filled grains	Total number of grains	Spikelet fertility	1000 grain weight	Phenotypic correlation with single plant yield
Days to flowering	**-0.022**	0.002	0.000	-0.015	-0.073	-0.068	0.013	-0.062	-0.001	**-0.225**
Plant height	0.003	**-0.013**	0.000	0.042	0.173	-0.089	-0.048	-0.012	-0.001	**0.054**
Panicle length	-0.001	-0.003	**0.002**	-0.010	-0.102	-0.034	-0.004	-0.020	0.000	**-0.172**
Number of tillers	0.003	-0.005	0.000	**0.121**	0.550	-0.039	-0.009	-0.023	-0.001	**0.597****
Number of productive tillers	0.003	-0.004	0.000	0.112	**0.592**	-0.036	-0.026	-0.001	0.000	**0.640****
Number of filled grains	0.003	0.003	0.000	-0.011	-0.047	**0.449**	0.189	0.120	0.000	**0.706****
Total number of grains	-0.001	0.003	0.000	-0.005	-0.064	0.357	**0.238**	0.005	-0.001	**0.532****
Spikelet fertility	0.007	0.001	0.000	-0.014	-0.004	0.279	0.006	**0.193**	0.001	**0.469****
1000 grain weight	0.004	0.002	0.000	-0.010	-0.034	-0.003	-0.035	0.033	**0.007**	**-0.035**

Diagonal and bold indicates the direct effect Residual effect = 0.105

Table 7. Direct and indirect effects of different traits on single plant yield in BC_2 generation under submergence – Cross 1

Traits	Days to flowering	Plant height	Panicle length	Number of tillers	Number of productive tillers	Number of filled grains	Total number of grains	Spikelet fertility	1000 grain weight	Phenotypic correlation with single plant yield
Days to flowering	**-0.002**	0.002	0.002	0.000	-0.007	0.153	-0.005	0.000	-0.005	**0.138**
Plant height	0.000	**0.011**	0.013	0.002	-0.164	0.057	-0.001	-0.001	-0.001	**-0.086**
Panicle length	0.000	0.004	**0.034**	0.002	-0.119	-0.047	0.002	0.000	0.000	**-0.124**
Number of tillers	0.000	-0.001	-0.007	**-0.011**	0.611	-0.053	0.003	-0.001	-0.003	**0.538****
Number of productive tillers	0.000	-0.003	-0.006	-0.010	**0.682**	-0.112	0.004	0.001	-0.002	**0.553****
Number of filled grains	0.000	0.001	-0.002	0.001	-0.089	**0.866**	-0.025	-0.006	0.001	**0.748****
Total number of grains	0.000	0.000	-0.002	0.001	-0.090	0.814	**-0.026**	-0.003	-0.001	**0.692****
Spikelet fertility	0.000	0.001	0.000	-0.001	-0.048	0.498	-0.007	**-0.010**	0.005	**0.439****
1000 grain weight	0.000	0.000	0.001	0.001	-0.064	0.023	0.001	-0.002	**0.026**	**-0.014**

Diagonal and bold indicates the direct effect Residual effect = 0.091

Table 8. Direct and indirect effects of different traits on single plant yield in BC_1 generation under submergence – Cross 2

Traits	Days to flowering	Plant height	Panicle length	Number of tillers	Number of productive tillers	Number of filled grains	Total number of grains	Spikelet fertility	1000 grain weight	Phenotypic correlation with single plant yield
Days to flowering	**0.012**	-0.001	0.001	0.016	0.225	-0.041	-0.060	0.011	0.000	**0.163**
Plant height	0.000	**-0.020**	0.000	0.017	0.142	0.061	0.076	-0.004	0.000	**0.272***
Panicle length	-0.004	-0.001	**-0.002**	-0.003	-0.083	-0.047	-0.048	-0.004	-0.001	**-0.193**
Number of tillers	0.005	-0.009	0.000	**0.038**	0.384	-0.023	-0.029	-0.001	0.000	**0.365****
Number of productive tillers	0.006	-0.006	0.000	0.031	**0.478**	-0.010	-0.016	0.002	0.000	**0.484****
Number of filled grains	-0.001	-0.003	0.000	-0.002	-0.012	**0.405**	0.429	0.042	0.000	**0.857****
Total number of grains	-0.002	-0.004	0.000	-0.003	-0.018	0.399	**0.435**	0.031	0.000	**0.840****
Spikelet fertility	0.002	0.001	0.000	-0.001	0.011	0.218	0.174	**0.078**	0.000	**0.483****
1000 grain weight	-0.002	0.000	0.001	-0.002	-0.048	0.008	0.007	0.001	**0.003**	**-0.031**

Diagonal and bold indicates the direct effect Residual effect = 0.094

Table 9. Direct and indirect effects of different traits on single plant yield in BC_2 generation under submergence – Cross 2

Traits	Days to flowering	Plant height	Panicle length	Number of tillers	Number of productive tillers	Number of filled grains	Total number of grains	Spikelet fertility	1000 grain weight	Phenotypic correlation with single plant yield
Days to flowering	**0.030**	0.001	0.000	0.002	0.130	-0.151	0.006	0.006	-0.001	**0.023**
Plant height	0.003	**0.008**	0.000	-0.004	-0.116	0.157	-0.010	-0.004	0.003	**0.038**
Panicle length	0.003	0.001	**0.002**	-0.001	-0.186	-0.020	-0.001	0.003	-0.003	**-0.204**
Number of tillers	0.005	-0.003	0.000	**0.012**	0.442	-0.038	0.004	0.000	-0.001	**0.421****
Number of productive tillers	0.007	-0.002	-0.001	0.009	**0.566**	-0.044	0.006	-0.002	0.000	**0.540****
Number of filled grains	-0.005	0.001	0.000	-0.001	-0.027	**0.920**	-0.070	-0.011	0.001	**0.809****
Total number of grains	-0.003	0.001	0.000	-0.001	-0.048	0.873	**-0.074**	-0.004	0.000	**0.746****
Spikelet fertility	-0.008	0.001	0.000	0.000	0.042	0.444	-0.014	**-0.023**	0.003	**0.446****
1000 grain weight	0.002	-0.002	0.001	0.001	-0.002	-0.048	0.000	0.005	**-0.013**	**-0.058**

Diagonal and bold indicates the direct effect Residual effect = 0.105

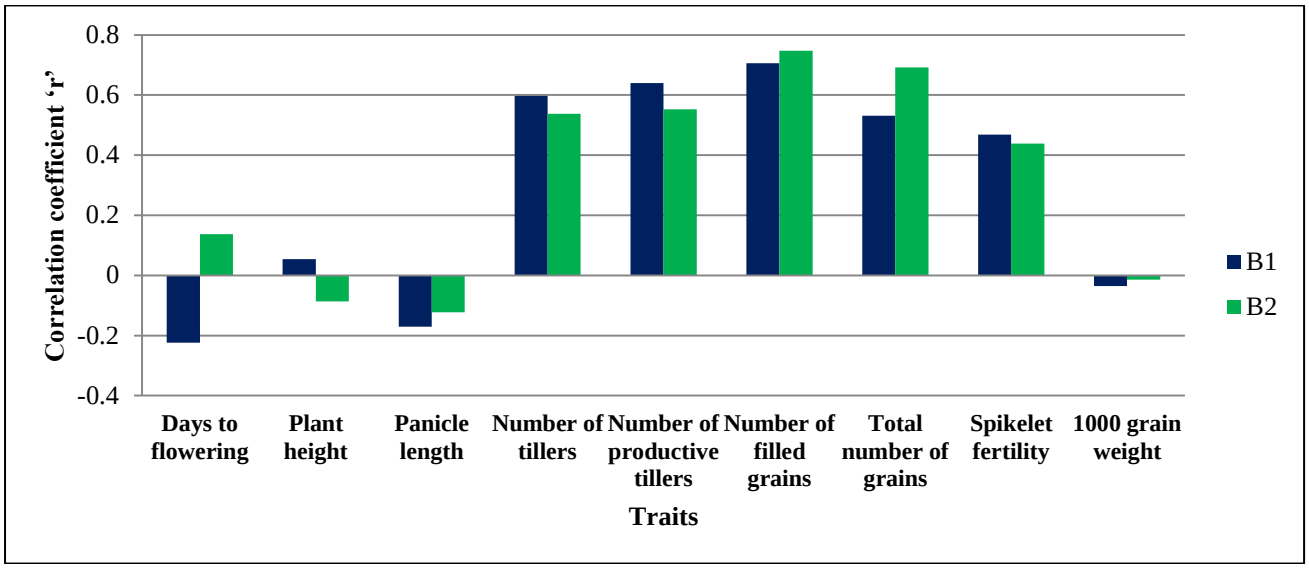


Fig. 1 Phenotypic Correlation coefficients between yield and yield components in cross 1 (ADT 43 x FR13A)

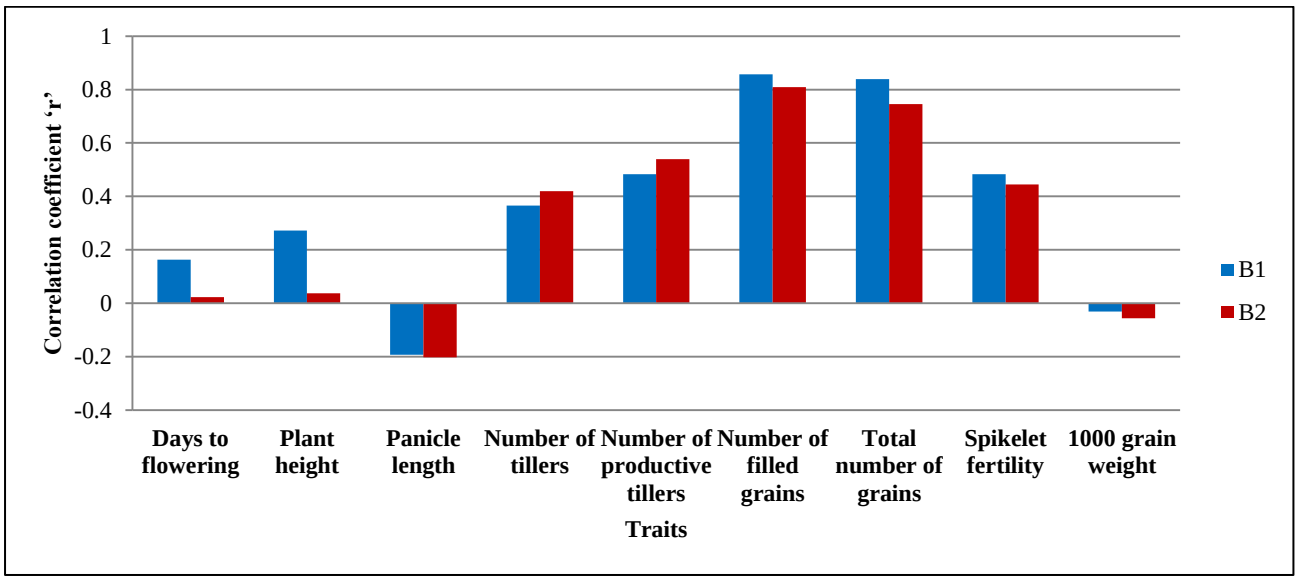


Fig. 2 Phenotypic Correlation coefficients between yield and yield components in cross 2 (IWP x FR13A)

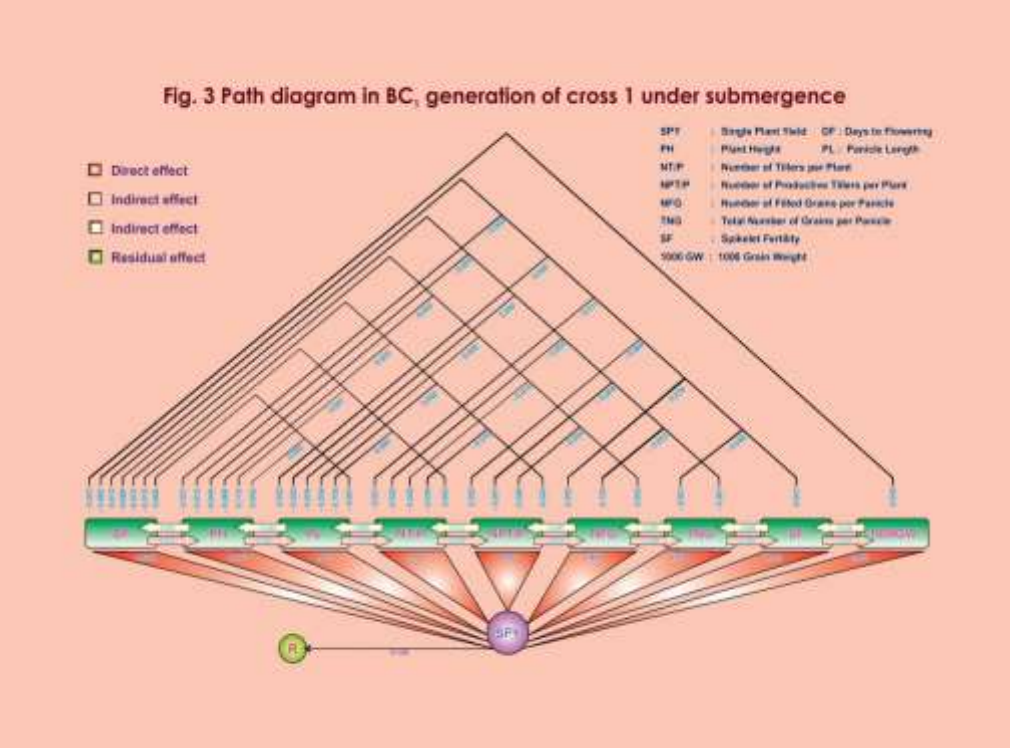


Fig. 3 Path diagram in BC_1 generation of cross 1 under submergence

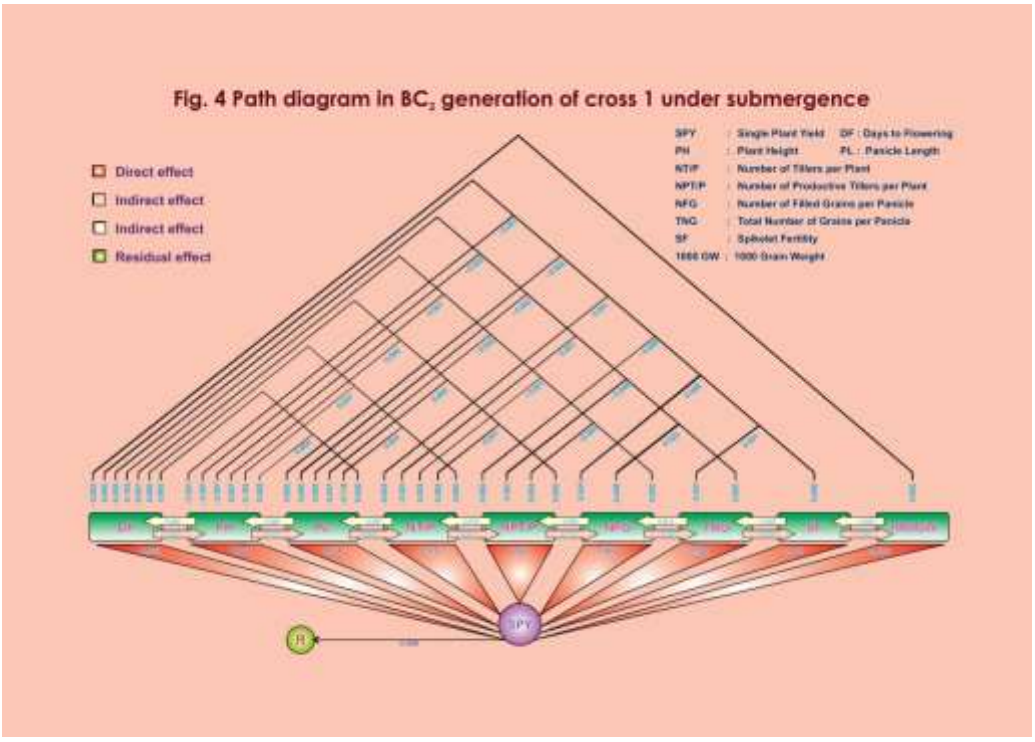
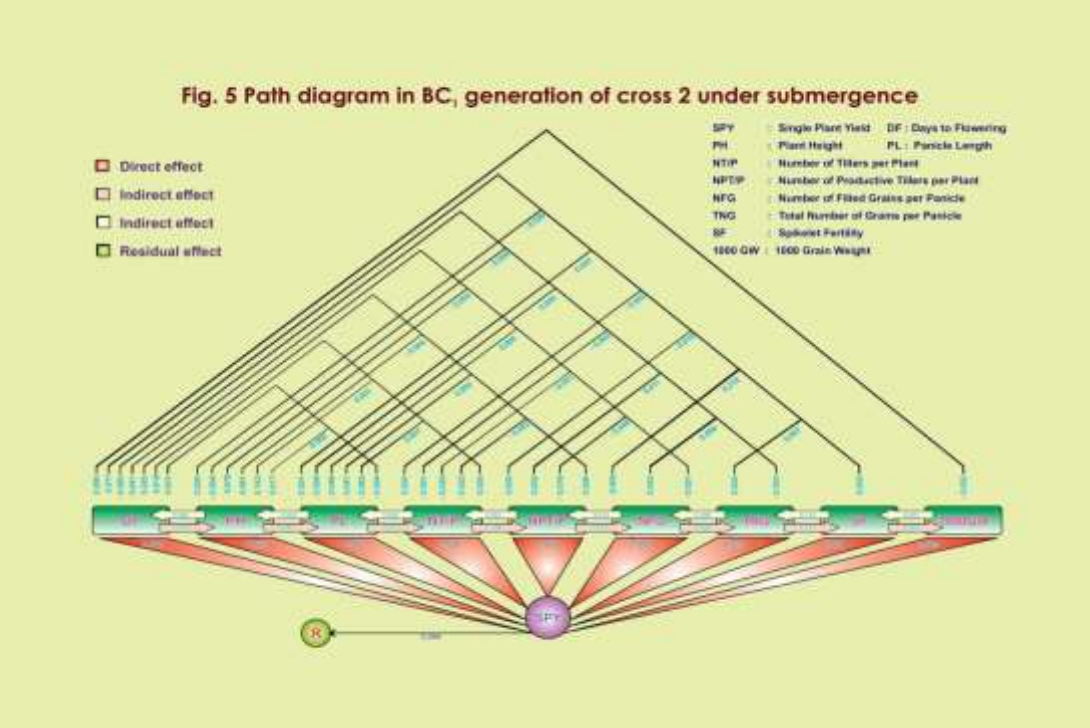
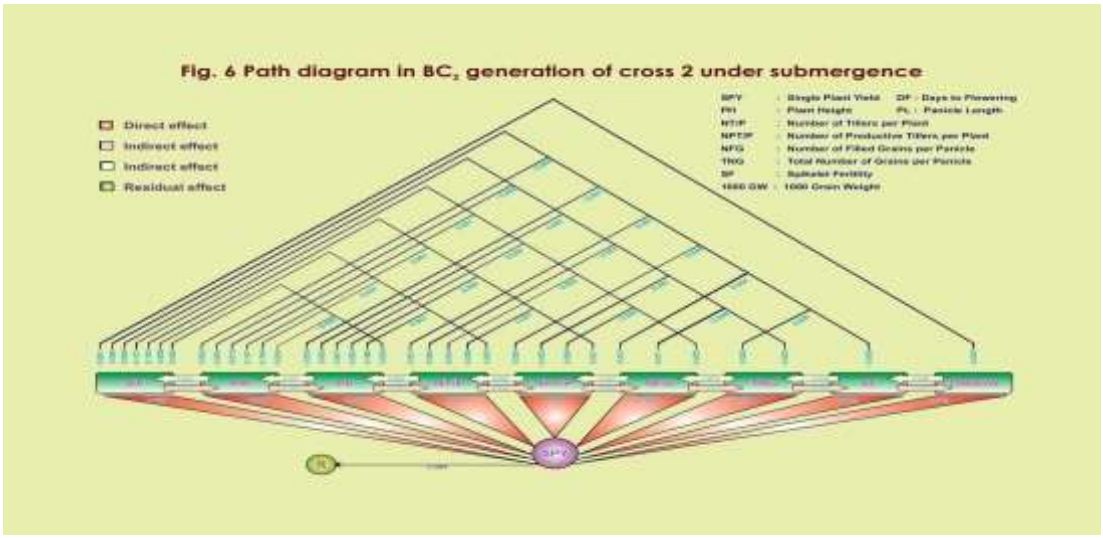


Fig. 4 Path diagram in BC_2 generation of cross 1 under submergence





Path Coefficient Analysis:

Cross 1(ADT43 x FR13A) and Cross 2 (IWP x FR13A)

In BC_1, the association of days to flowering with single plant yield in cross 1 was negative and non-significant (-0.225). The trait days to flowering had positive but non-significant (0.138) association with single plant yield under submergence condition in second back cross generation (Tables 6 and 7) (Fig. 3 and 4). In cross 1, the direct effect of days to flowering on single plant yield was negligible in all the generations namely BC_1 and BC_2. Likewise, its indirect effect through other traits was also either negligible or low in all the three generations studied. Days to flowering expressed positively non-significant association with single plant yield in all the generations *viz.*, BC_1 (0.163) and BC_2 (0.023) of cross 2 under submergence condition. (Tables 8 and 9) (Fig. 5 and 6)

In BC_1 and BC_2 the direct effect of plant height on single plant yield was negligible in cross 1. Similarly, its indirect effect through all other traits was either negligible or low under submergence condition in cross 1. The direct effect of panicle length on single plant yield was negligible in BC_1 and BC_2. Likewise, its indirect effect on single plant yield through

other traits was also either negligible or low in cross 1 (Tables 6 and 7).

The indirect effect of number of tillers on single plant yield through other traits was also negligible, except for the trait number of productive tillers in all the generations *viz*., BC_1 (0.550) and BC_2 (0.611) which were highly positive (Tables 6 and 7). The trait number of tillers showed positive and significant association with single plant yield in BC_1 (0.365) and BC_2 (0.421) of cross 2. In cross 2, the indirect effect of number of tillers through other traits was either negligible or low, except for the trait number of productive tillers (positive and high) in BC_1 and BC_2. (Tables 8 and 9) (Fig. 5 and Fig. 6)

The portioning of phenotypic correlation coefficient of different components with single plant yield into direct and indirect effects was revealed that the direct effect of number of productive tillers on single plant yield was positively high in BC_1 (0.592) and BC_2 (0.682) in cross 1 studied under submergence condition. In both the generations, its indirect effect on single plant yield through other traits was either negligible or low in cross 1. The direct effect of number of productive tillers on single plant yield was positively high in BC_1 (0.478) and BC_2 (0.566) of cross 2. Its indirect effect on single plant yield through other traits was negligible. (Fig. 3 to Fig. 6)

The direct effect of number of filled grains on single plant yield was positive and high in BC_1 (0.449) and BC_2 (0.866). The indirect effect of number of filled grains on single plant yield through all other traits was either negligible or low in cross 1 (Tables 6 and 7). In cross 2, its direct effect on plant yield was positive and high in BC_1 and BC_2. Its indirect effect of number of filled grains through other traits was negligible, except for total number of grains (positive and high) in BC_1 (0.429). The direct effect of total number of grains per panicle on single plant yield was positive and moderate (0.238) in BC_1. The indirect effect of total number of grains through all other traits was negligible except for number of filled grains (positive and high) in all the generations (BC_1 and BC_2) studied.

Positive and significant association with grain yield exhibited by total number of grains per panicle in all the generations *viz*., BC_1 (0.840) and BC_2 (0.746) of cross 2. Its direct effect on single plant was positively high in BC_1. In BC_2, the direct effect of total number of grains per panicle on single plant was negligible (Tables 8 and 9). However, in BC_1 and BC_2 it expressed positive and high indirect effect through number of filled grains. The indirect effects through rest of the characters were slight or ignorable in first and second back cross generations. However, in cross 2 productive tillers per plant, number of filled grains per panicle and total number of grains per panicle in B_1 generation and number of productive tillers per plant and number of filled grains per panicle in B_2 generation had high direct effect on single plant yield. In cross 1 the indirect effect of spikelet fertility through other traits was either negligible or low, except for number of filled grains which was positive and high (BC_2) and positive and moderate in BC_1. The indirect effect of spikelet fertility on plant yield through other traits was negligible, except number of filled grains, where it was positive and moderate in BC_1 and positive and high in BC_2 of cross 2.

The direct effect of 1000 grain weight with single plant yield was negligible in both BC_1 and BC_2 generations studied under submergence. Its indirect effect through other traits was either negligible, or low in BC_1 and BC_2 of cross 1(Tables 6 and 7) (Fig. 3 and Fig. 4). In BC_1 and BC_2, the association of 1000 grain weight with single plant yield was negative and non-significant in cross 2. (Tables 8 and 9) (Fig. 5 and Fig. 6)

Discussion

Correlation coefficient analysis:

Cross 1 (ADT43 x FR13A) and Cross 2 (IWP x FR13A)

In the present study, the single plant yields had positive and significant association with all the traits except days to first flowering, plant height and panicle length, in cross 1 and cross 2 in BC_1 and BC_2 generations (Table 2 to

5). This association indicated that there is a possibility of contribution of these traits for improving grain yield. Number of tillers per plant had positive and significant association with single plant yield was earlier reported by Saravanan and Sabesan (2009), Gunasekaran *et al.* (2010), Yogameenakshi and Vivekanandan (2010), Gopikannan and Ganesh (2013), Touhiduzzamam *et al.* (2016) and Singh *et al.* (2016); number of productive tillers per plant with grain yield per plant reported by Gunasekaran *et al.* (2010), Shiva Prasad *et al.* (2013), Krishnamurthy *et al.* (2014) and Singh *et al.* (2016); number of filled grains per panicle with grain yield per plant by Mohana Krishnan *et al.* (2009), Shiva Prasad *et al.* (2009), Akinwale *et al.* (2011), Singh et al. (2016) and Pradhan *et al.* (2017); total number of grains per panicle with grain yield per plant by Borbora *et al.* (2005), Shiva Prasad *et al.* (2009), Gunasekaran *et al.* (2010), Shiva Prasad *et al.* (2013), Gopikannan and Ganesh (2013) and Singh *et al.* (2016); Spikelet fertility with grain yield per plant earlier reported by Gopikannan and Ganesh (2013), Touhiduzzaman *et al.* (2016) and Pradhan *et al.* (2017); 1000 grain weight with grain yield per plant by Raju *et al.* (2004), Afzal Zahid *et al.* (2006), Anbumalarmathi and Nadarajan (2008), Yogameenakshi and Vivekanandan (2010), Shiva Prasad *et al.* (2013), Singh *et al.* (2016) and Pradhan *et al.* (2017). The negative and significant association of days to first flowering with grain yield per plant was reported by Yogameenakshi and Vivekanandan (2010), Shiva Prasad *et al.* (2013) and Dhurai *et al.* (2016), plant height with grain yield per plant by Priya (2003), Afzal Zahid *et al.* (2006), Anbumalarmathi and Nadarajan (2008), Shiva Prasad *et al.* (2013) and Salim *et al.* (2016); panicle length with grain yield per plant by Ahmed *et al.* (1991), Vanniarajan *et al.* (1996), Borbora *et al.* (2005) and Sarkar *et al.* (2006).

The inter correlation between yield component characters may affect the selection for component traits either in favourable or unfavourable direction. The knowledge on inter correlation between yield component traits may facilitate breeders to decide upon the intensity and direction of selection to be given on related traits for the simultaneous improvement of several traits.

There was a positive and significant correlation between days to first flowering with panicle length, number of tillers per plant and number of productive tillers per plant in both the crosses of all the three generations. This was in corroboration with the earlier workers *viz.,* Ushakumari (1995), Mokate *et al.* (1998), Shiva Prasad *et al.* (2013), Singh *et al.* (2016) and Salim *et al.* (2016) for plant height; Shiva Prasad *et al.* (2013) for number of filled grains per panicle; Yogameenakshi *et al.* (2004), Shiva Prasad *et al.* (2009) and Akhtar *et al.* (2010) for total number of grains per panicle. Plant height showed significant and positive association with number of tillers per plant in BC_1 and BC_2 generations of cross 1 and cross 2. This is in confirmation with Michael Gomez and Rangasamy (2002) and Suman *et al.* (2006) for number of tillers per plant. A positive and significant association was established by number of tillers with number of productive tillers per plant in all the three generations of both the crosses. This was in agreement with earlier workers like Krishnamurthy *et al.* (2014) and Singh *et al.* (2016)

The number of filled grains per panicle established a positive and significant association with total number of grains per panicle and spikelet fertility in BC_1 and BC_2 generations of both the crosses. This was in accordance with the results obtained by Dhurai *et al.* (2016) for total number of grains per panicle; Singh *et al.* (2016) and Pradhan *et al.* (2017) for spikelet fertility. Total number of grains per panicle had positive and significant association with spikelet fertility in all the three generations. This is in conformity with the earlier findings by Patil and Sarawgi (2005), Satyanarayana *et al.* (2005) and Salim *et al.* (2016) for spikelet fertility. Positive association between spikelet fertility and 1000 grain weight was noticed in both the crosses. This was in agreement with the earlier findings of Gopikannan and Ganesh (2013), Singh *et al.* (2016) and Pradhan *et al.* (2017).

As from the correlation study it was evident that the yield components traits *viz*., number of tillers per plant, number of productive tillers per plant, number of filled grains per panicle, total number of grains per panicle and spikelet fertility are important traits for improving yield since they had significant and positive correlation with single plant yield and also had a positive inter correlation among themselves. Therefore, these traits are to be given priority during the selection programme for improving yield under submergence condition in rice.

Path Coefficient Analysis:

Cross 1(ADT43 x FR13A) and Cross 2 (IWP x FR13A)

The present study revealed that, number of productive tillers per plant and number of filled grains per panicle had high direct effect on single plant yield in both the generations of cross 1 (Table 6 and 7). This was in accordance with earlier findings of Shiva Prasad *et al.* (2009), Gunasekaran *et al.* (2010), Jayasudha and Deepak Sharma (2010), Gopikannan and Ganesh (2013), Krishnamurthy *et al.* (2014) and Singh *et al.* (2016) for number of productive tillers per plant; Gunasekaran *et al.* (2010), Akhtar *et al.* (2010), Gopikannan and Ganesh (2013) and Pradhan *et al.* (2017) for number of filled grains per panicle. However, in cross 2 productive tillers per plant, number of filled grains per panicle and total number of grains per panicle in BC_1 generation and number of productive tillers per plant and number of filled grains per panicle in BC_2 generation had high direct effect on single plant yield (Table 8 and 9). This was in accordance with earlier findings of Gopikannan and Ganesh (2013) and Singh *et al.* (2016) for number of productive tillers per plant; Shiva Prasad *et al.* (2013), Dhurai *et al.* (2016) and Pradhan *et al.* (2017) for number of filled grains per panicle; Gopikannan and Ganesh (2013) and Touhiduzzaman *et al.* (2016) for spikelet fertility. The remaining traits mostly showed either low or negligible direct effect on grain yield per plant. Besides this, the indirect effects are concerned, the yield component traits had moderate to high indirect effects on grain yield only through number of productive tillers per plant and number of filled grains per panicle. This was supported by Mahto *et al.* (2003), Vaithiyalingam and Nadarajan (2005), Zahid *et al.* (2006), Sankar *et al.* (2006), Krishnamurthy et al. (2014), Singh *et al.* (2016) and Touhiduzzaman *et al.* (2016). The traits number of productive tillers per plant, number of filled grains per panicle influenced single plant yield via total number of grains per panicle. This was in conformity with the reports of Dhurai *et al.* (2016), Singh *et al.* (2016) and Pradhan *et al.* (2017).

Conclusion

As from the correlation study it was evident that the yield components traits *viz*., number of tillers per plant, number of productive tillers per plant, number of filled grains per panicle, total number of grains per panicle and spikelet fertility are important traits for improving yield since they had significant and positive correlation with single plant yield and also had a positive inter correlation among themselves. Therefore, these traits are to be given priority during the selection programme for improving yield under submergence condition in rice. Path coefficient analysis concluded that selection for number of productive tillers per plant and number of filled grains per panicle have be given due weight age during selection since they had positive correlation with grain yield, positive inter correlation among themselves and high direct and indirect effect on grain yield through total number of grains per panicle under submergence condition in rice.

Acknowledgements

This work was financially supported by the University Grants Commission, New Delhi. We thank the ICAR- Indian Institute of Rice Research (Formerly CRRI), Cuttack and Tamil Nadu Rice Research Institute, Aduthurai, TNAU for providing rice genotypes for the investigation. We also thank the Department of Plant Breeding and Genetics, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai, Tamil Nadu for their technical help and support during the conduct of study.

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Source of support: Nil; **Conflict of interest:** Nil.

Cite this article as:

Muthuvijayaragavan, R. and E. Murugan. "Character Association and Stress Indices Analysis for Yield Components in Sub 1 QTL Introgressed Backcross Lines of Rice (*Oryza Sativa* L.)." *Annals of Plant Sciences*.11.04 (2022): pp. 5013-5032.

DOI: http://dx.doi.org/10.21746/aps.2022.11.4.2