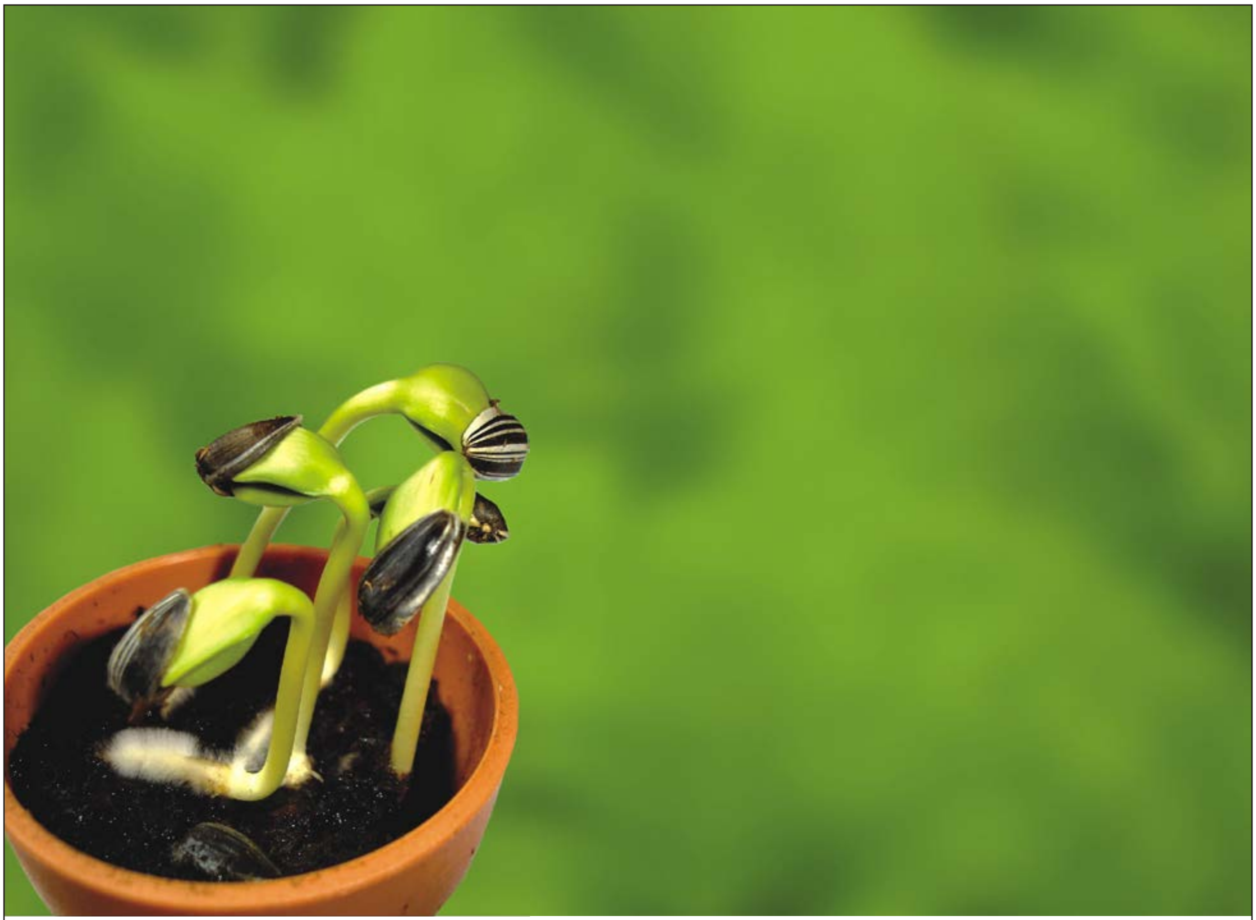

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Evaluation of Genetic Potential of Parents and Their Hybrids for Drought Tolerance in Rice (*Oryza sativa* L.)

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Abstract: Drought is an important limiting factor, adversely affecting the crop production in recent years. In order to design an efficient breeding programme for synthesis of new varieties with virtues of drought tolerance and high yielding ability, it is necessary to identify potential parents that combine well for both yield and drought tolerance. Hence, the present investigation was undertaken to study the genetic potentiality of eight lines (drought tolerance genotypes) and five testers (high yielding varieties) along with their resultant 40 hybrids were assessed through combining ability estimates for 15 physio-morphological and yield contributing traits under moisture stress condition. Four lines viz., Moroberekan, CT 9993, Norungan and Nootripathu and two testers viz., MDU 5 and ASD 16 were identified as potential parents based on mean and *gca* effects. Four cross combinations viz., Moroberekan/MDU 5, CT 9993/MDU 5, Moroberekan/CO 47 and Norungan/MDU 5 were identified as best crosses to get desirable segregants for recombination breeding under water stress condition.

Key words: Rice, genetic potential, physio-morphological traits, moisture stress

INTRODUCTION

Drought is a major natural hazard that has been historically associated with food scarcity of varying intensities including those that have resulted in major famines. Global yield loss due to drought was estimated as high as €3.51 billion annually. Rice is the most important food crop in Asia, in view of its recognition as an important food crop requiring constant and continued research efforts to stabilize production. Rice is cultivated in a wide range of ecosystems under varying temperature and water regimes. In India, 58% of the rice growing area is under rainfed condition. Drought stress, therefore, is an important limitation to rice production in India, particularly among low income and subsistence farmers. Unless there is in built tolerance for drought, increasing grain yield will be difficult. Therefore, the development of drought resistant cultivars with a higher yield potential is one of the main objectives of drought tolerance rice breeding for boosting rice production in rainfed low lands.

In order to design an efficient breeding programme for synthesis of varieties with virtues of drought tolerance and high yielding ability, it is necessary to identify potential rice parents and their hybrids that combine well for both high yielding and drought tolerance. Studies on combining ability help in selection of superior parents for hybridization and provide knowledge of genetic behavior of various economic traits (physio-morphological traits) which are important for a successful breeding programme. The effectiveness of selection for secondary traits to improve yield under water-limiting conditions has been demonstrated in rice by Manickavelu *et al*. (2006), maize

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(Chapman and Edmeades, 1999), wheat (Richards *et al*., 2000) and sorghum (Tuinstra *et al*., 1998). However, recent evidences suggest that direct selection for yield under stress is also effective, if replicated field screening is adopted (Atlin *et al*., 2004).

The main objectives of the present investigation was to obtain a genotype having high grain yield along with drought tolerant characters and also to identifying the best combining parent and their crosses on the basis of their general and specific combining ability effects under drought situation.

MATERIALS AND METHODS

The present investigation was conducted at Research Farm, Agricultural College and Research Institute, Madurai (latitude: 9.54' E; longitude: 78.8' N; altitude: 147 m MSL) during October 2004-January 2005 and June 2005- September 2005.

The experimental materials consisted of eight drought tolerant genotypes viz., Norungan (L_1), Mattaikar (L_2), CT 9993 (L_3), Moroberekan (L_4), NPT 107 (L_5), CPMB ACM 03 015 (L_6), CPMB ACM 03 017 (L_7) and Nootripathu (L_8) (lines) and five high yielding cosmopolitan rice varieties viz., MDU 5 (T_1), CO 47 (T_2), IR 50 (T_3), ASD 16 (T_4) and ASD 18 (T_5) (testers). Crossing was carried out by following in a Line × Tester mating design (Kempthorne, 1957) during Rabi 2004-2005. For crossing, wet cloth method suggested by Chaisang *et al*. (1967) was followed and maximum numbers of crosses were made to develop sufficient F_1 seeds. The F_1 hybrids of the resultant 40 hybrids along with their parents were raised in a Randomized Block Design (RBD) replicated twice with a spacing of 20×15 cm during Kharif, 2005. Single seedling was transplanted per hill for each hybrid in two rows of three meter length. IR 50, the susceptible variety for drought was raised along the borders as an indicator of moisture stress. The experiment was conducted in rainfed conditions with supplemented irrigation as needed. At peak tillering phase, irrigation was withheld in order to impose drought. IR 50, the stress indicator started to show stress symptoms within 3-5 days. In rice 70% relative water content (RWC) was previously demonstrated to be a relevant screening tool of drought tolerance in cereals, as well as good indicator of plant water status (Teulat *et al*., 2003). In rice, once the plants attain 70% RWC, it indicates the real physiological stress of the irrespective of the environment (Babu *et al*., 1999). Hence, the RWC was taken at regular intervals in each genotype.

Phenotypic Parameters Recorded

When each genotype attain 70% RWC, the drought tolerant parameters viz., leaf rolling, leaf drying were scored and the field was re-irrigated. After one week, the drought recovery rate was recorded. In each replication, 10 plants were randomly selected per genotype for recording observations on drought tolerant attributes viz., days to 70% Relative Water Content (RWC), Leaf Rolling (LR), Leaf Drying (LD), Drought Recovery Rate (DRR), Root Length (RL), Root Dry Weight (RDW), root: shoot ratio (R/S) were recorded. The yield components traits viz., days to 50% flowering (DFF), Plant Height (PH), Productive Tillers per Plant (PT), Grains per Panicle (GP), Spikelet Fertility (SF), Harvest Index (HI) and Grain Yield per plant (GY) were recorded. The drought tolerance attributes were recorded as follows:

Days to Attain 70% Relative Water Content (70% RWC):

Stress was induced at peak tillering phase on 60 days after sowing. Observations were recorded repeatedly every day till RWC reaches 70%. Leaf sampling was done at midday. In each selected plant, days to 70% RWC was recorded as follows:

A sample of 0.5 g of fresh, healthy and unblemished leaf material, excluding the apex and collar regions, was collected from each of the ten selected plants from each genotype. After taking the fresh weight (FW), the samples were placed in petri dishes containing distilled water and kept in a moist chamber for 24 h to obtain full turgidity. After 24 h, the samples were removed from distilled water, blotted dry and the Turgid Weight (TW) was recorded. Then the turgid leaf samples were kept in hot air oven at 60°C overnight and the oven dry weight was determined. The RWC was calculated using the formula suggested by Kramer (1969).

$$\text{RWC (\%)} = \frac{\text{Field fresh weight} - \text{Oven dry weight}}{\text{Turgid weight} - \text{Oven dry weight}} \times 100$$

Leaf Rolling and Leaf Drying

Leaf rolling and leaf drying were recorded at 70% RWC. It is scored on an scale of 0 to 9 according to Standard Evaluation System adopted for Rice (IRRI, 1996).

Drought Recovery Rate

The crop was irrigated after the stress period upto maturity. Drought recovery rate was recorded seven days after irrigation, according to Standard Evaluation System adopted for Rice (IRRI, 1996).

Root Length

At physiological maturity, selected plants were uprooted by giving a deep dig near the base after watering and the maximum root length of the longest root was recorded in centimeter.

Root Dry Weight

Roots of the selected plants at the time of harvest were cut from the stem, dried moisture free in a hot air oven at 80°C for 48 h (till attaining constant weight), weighed and recorded in gram.

Root: Shoot Ratio:

The root weight of selected plants was recorded as mentioned above. The shoot weight was recorded separately after drying the shoot portion including grains in hot air oven at 80°C for 48 h till reaching constant weight. Root : Shoot ratio was worked out as follows,

$$\text{Root : Shoot ratio} = \frac{\text{Root dry weight (g)}}{\text{Shoot dry weight (g)}}$$

After ascertaining the significance among the genotypes, the data were subjected to combining ability analysis following Kempthorne (1957).

RESULTS AND DISCUSSION

Genetic Potentiality of Parents

The analysis of variance for combining ability (Line × Tester) analysis revealed that, significant differences among the hybrids, lines, testers and line × tester interaction for all the characters studied. Parents and hybrids that had low leaf rolling score, leaf drying score, drought recovery rate, days to 50% flowering and plant height (short stature) and, while for other traits, parents and hybrids that had more days to attain 70% relative water content, root length, root dry weight, root:shoot ratio, productive tillers per plant, grains per panicle, spikelet fertility, harvest index and grain yield per plant were desirable for drought tolerance rice breeding programme.

Combining ability studies helps in the hybridization programme, besides elucidating the nature and magnitude of gene action involved in the inheritance of the character. Parents with high *gca* effects are desirable for obtaining useful segregants in early generations (Manonmani and Fazullah Khan, 2005). Parents that had negative and significant *gca* effects were considered for days to 50% flowering, leaf rolling, leaf drying, drought recovery rate and plant height while for other traits, parents with positively significant *gca* effects were taken into consideration. Anbumalarmathi and Nadarajan (2006) reported that parents with high mean performance may not be able to transmit their superior traits into hybrids and hence they insisted the need for combining ability of parents also. Evaluation of parents based on mean and *gca* effects might result in identification of parents with good reservoir of superior genes. Hence, both *per se* and *gca* effects were taken into account for parental selection.

On the basis of mean values and *gca* effects together, the valuable genotype, line Moroberekan (L_4) possessed high mean value and *gca* effects for four drought tolerance and six yield component traits viz., days to 70% RWC, root length, root dry weight, root: shoot ratio, productive tillers per plant, panicle length, grains per panicle, spikelet fertility, harvest index and grain yield. The next best line was CT 9993 (L_3), which expressed favourable mean and *gca* effects for six important traits viz., root length, root dry weight, root: shoot ratio, plant height, panicle length and grain yield. It was followed by the lines Norungan (L_1) and Nootripathu (L_8), which showed significantly high mean value and *gca* effects for important physio-morphological traits viz., days to 70% RWC, leaf rolling, leaf drying, drought recovery rate and days to 50% flowering. Among testers, MDU 5 (T_1) was adjudged as the best parent, since it showed high mean and *gca* effects for seven traits viz., leaf rolling, root length, root dry weight, root: shoot ratio, days to 50% flowering, plant height and spikelet fertility followed by ASD 16 (T_4) for four yield contributing traits (Table 1). Thus, an overview of *per se* performance and *gca* effects of parents revealed that multiple crosses involving Moroberekan, CT 9993, MDU 5 and ASD 16 would be considered as invaluable sources of genetic materials as they might throw desirable segregants possessing drought tolerance coupled with higher yield performance under moisture stress condition.

Potentiality of Hybrids for Recombination Breeding

The basic idea of hybridization is to combine favourable genes present in different parents into a single genotype. The genetic architecture of the progenies will be improved by effective recombination of parents in a cross combination. Development of hybrids in rice without employing male sterile lines is very limited. Instead, recombination breeding has been the major avenue for rice improvement over decades because of high magnitude of fixable additive gene action (Patil *et al*., 2003). To get outstanding recombinants in segregating generations, the parents of the hybrids must be good general combiners for the characters to which improvement is sought (Gravois and McNew, 1993). In case of hybrids with significant *sca* effects, selection in early segregating generation is likely to fail as the *sca* effects mask the true performance of the selected plants. Therefore, it will be useful to select only those hybrids showing parents with significant *gca* effects and non significant *sca* effects for recombination breeding, since it is likely to throw segregants with favourable genes derived from both the parents (Nadarajan and Rangaswamy, 1990). Therefore, the hybrids for recombination breeding were selected based on significant *gca* effects of both the parents and with non-significant *sca* effects of hybrids for each trait (Table 2).

The hybrid Moroberekan/MDU 5 was recommended for recombination breeding, since it exhibited non-significant *sca* effects with significantly favorable *gca* effects for five traits viz., days to 70% RWC, leaf rolling, root dry weight, root: shoot ratio and productive tillers per plant. The next best hybrids viz., CT 9993/MDU 5 and Moroberekan/CO 47 were suitable for recombination breeding for four traits each. The former satisfied the said criteria for 70% RWC, leaf drying, root shoot ratio, productive tillers per plant and grains per panicle while, the later also four traits viz., 70% RWC, root

Table 1: General combining ability effects and mean of parents for various traits under moisture stress condition in rice

Parents	70 % RWC	LR	LD	DRR	RL (cm)
L_1	0.61* (12.45)*	-0.47* (2.80)*	-0.15 (2.20)*	-0.36* (1.80)*	-0.17 (18.50)*
L_2	-0.62* (10.75)	0.18 (3.60)	-0.10 (3.00)	-0.37* (3.20)	-2.38* (16.50)
L_3	0.53* (10.50)	0.13 (3.60)	-0.05 (3.10)	-0.35* (2.90)	4.80* (20.15)*
L_4	0.49* (12.10)*	-0.44* (4.00)	-0.29* (2.75)	0.18 (2.30)	2.08* (19.40)*
L_5	-1.71* (10.00)	1.52* (5.00)	1.00* (3.90)	1.03* (3.95)	-3.88* (15.30)
L_6	0.42 (10.25)	-0.26 (2.80)*	-0.44* (3.20)	0.53* (2.90)	-0.80* (16.70)
L_7	-0.61* (12.05)*	-0.36* (3.00)	-0.28* (2.20)*	0.21 (1.80)	-0.90* (17.20)
L_8	0.91* (12.25)*	-0.32* (3.11)	-0.31* (2.15)*	-0.35* (2.40)	1.25* (19.10)*
SE (5%)	0.21	0.15	0.13	0.16	0.14
T_1	0.67* (9.00)	-0.59* (4.90)*	-0.52* (3.90)	-0.42* (3.50)	1.30* (15.00)*
T_2	0.10 (8.00)	-0.11 (5.30)	-0.37* (4.20)	0.02 (3.90)	-0.84* (13.75)
T_3	-1.92* (7.00)	0.07 (7.40)	0.53* (4.80)	0.51* (5.60)	-2.62* (13.25)
T_4	0.91* (8.75)	0.27* (5.30)	0.26* (3.80)	-0.01 (3.60)	0.32* (14.00)
T_5	0.23 (8.20)	0.35* (5.80)	0.11 (4.00)	-0.10 (4.00)	1.84* (13.75)
SE (5%)	0.18	0.13	0.11	0.24	0.11

Parents	RDW (g)	R/S ratio	DFF	PH (cm)	PT
L_1	-0.24* (2.83)*	0.01* (0.07)	-0.61* (88.50)	3.50* (126.50)	-0.37* (6.80)
L_2	-0.39* (2.50)	-0.01* (0.07)	-3.21* (88.50)	0.92* (124.50)	-2.25* (6.40)*
L_3	0.88* (3.05)*	0.01* (0.09)*	2.89* (92.50)	-5.20* (91.50)*	2.56* (7.20)
L_4	0.78* (2.90)*	0.01* (0.09)*	2.49* (95.00)	3.42* (96.00)*	0.45* (9.10)*
L_5	-0.63* (2.20)	-0.01* (0.05)	1.69* (86.00)*	-4.78* (85.00)	2.46* (7.35)
L_6	-0.21* (2.55)	0.001 (0.06)	-0.71* (86.50)*	8.57* (126.00)	-0.07 (6.40)
L_7	-0.16* (2.65)	0.001 (0.08)*	0.57* (82.50)*	-2.83* (91.00)*	-1.28* (6.50)
L_8	-0.04 (2.90)*	-0.01* (0.08)*	-3.11* (84.50)*	-3.62* (119.50)	-1.51* (7.00)
SE (5%)	0.03	0.001	0.27	0.33	0.15
T_1	0.47* (2.20)*	0.02* (0.06)*	5.74* (77.00)*	-4.18* (69.50)*	1.21* (9.35)
T_2	-0.16* (1.95)	0.001* (0.05)	3.97* (86.00)	2.41* (80.60)	0.30* (13.10)*
T_3	-0.54* (1.90)	-0.01* (0.04)	-2.03* (79.50)*	3.14* (73.90)*	0.33* (11.10)
T_4	-0.22* (2.05)	0.001* (0.05)	4.88* (85.00)	5.89* (81.00)	-1.20* (10.14)
T_5	-0.44* (1.95)	0.001* (0.05)	-1.08* (82.50)	-0.99* (74.10)*	-0.63* (12.10)*
SE (5%)	0.02	0.0004	0.21	0.26	0.12

Parents	PL (cm)	GPP	SF (%)	HI	GY (g)
L_1	-0.53 (23.00)	-8.48* (98.50)	0.03 (84.00)*	-0.04* (0.30)	0.48 (8.00)
L_2	-1.69* (21.35)	-17.05* (91.85)	-4.94* (83.00)	-0.04* (0.29)	-1.57* (8.35)
L_3	1.98* (24.75)*	12.62* (108.35)	2.10* (83.05)*	0.07* (0.34)	1.25* (9.90)*
L_4	1.25* (24.35)*	8.61* (118.00)*	2.28* (83.75)*	0.06* (0.38)*	1.14* (10.10)*
L_5	0.09 (22.60)	0.80 (111.15)*	-1.18* (78.50)	-0.01* (0.31)	-0.85* (9.50)
L_6	2.67* (27.10)*	16.06* (126.75)*	1.64* (81.00)	-0.03* (0.29)	0.24 (9.50)
L_7	-2.62* (22.25)	-11.49* (116.00)*	-0.18 (81.50)	0.02* (0.36)*	-0.67 (9.60)
L_8	-1.15* (21.45)	-1.06* (92.25)	0.26 (83.70)*	-0.04* (0.31)	-0.05 (8.30)
SE (5%)	0.50	0.50	0.22	0.001	0.36
T_1	-0.67 (22.04)	-1.94* (110.25)	1.51* (78.50)*	0.02* (0.31)	0.01 (11.00)
T_2	0.07 (24.30)	5.10* (121.75)*	-0.16 (76.00)	-0.01* (0.30)	0.14 (11.50)
T_3	-1.53* (22.70)	-5.97* (110.50)	-2.11* (74.50)	-0.05* (0.29)	-1.40* (10.50)
T_4	2.73* (26.40)*	1.68* (121.25)*	0.98* (78.25)*	-0.03* (0.35)*	1.05* (12.50)*
T_5	-0.61 (25.35)*	1.14* (118.90)*	-0.22 (77.10)	0.001* (0.29)	0.48 (11.75)
SE (5%)	0.40	0.40	0.17	0.0004	0.37*

Significant at 5 % level ; Note: Values in parenthesis indicate the respective mean values

shoot ratio, productive tillers per plant and spikelet fertility. The hybrid Norungan/MDU 5 also satisfied the said criteria for four drought tolerant traits viz., leaf rolling, leaf drying, drought recovery rate, root shoot ratio and days to 50% flowering, while, the cross Nootripathu/MDU 5 also satisfy the above criteria for leaf rolling, leaf drying, days to 50% flowering and plant height. The similar results have been reported already in rice under moisture stress by Anbumalarmathi and Nadarajan (2006).

In conclusion, direct yield improvement under moister stress environment is difficult. Hence, yield improvement in water limited environments could be achieved by identifying secondary traits contributing to drought tolerance and selecting for those traits in breeding programme. Taking in to

Table 2: Significant *gca* and non-significant *sca* effects of parents and hybrids respectively for different traits under stress

Parents/hybrids	Traits associated with significant *gca* effects/non-significant *sca* effects
Norungan	70% RWC, LR, LD, DRR, R/S, DFF
Nootripathu	70% RWC, LD, RL, DFF, PH
Moroberekan	70% RWC, LR, LD, RL. RDW, R/S, PT, PL, GPP, SF, HI, GY
CT 9993	70% RWC, DRR, RL. RDW, R/S, PT, PL, GPP, SF, HI, GY
MDU 5	70% RWC, LR, LD, DRR, RL. R/S, DFF, PH, PT, SF, HI
ASD 16	70% RWC, LR, LD, RL. R/S, PL, GPP, SF, GY
Hybrids	
Norungan/MDU 5	LR (-0.06), LD (0.10), DRR (0.42), R/S (-0.01), DFF (0.55)
Norungan/CO 47	LD (0.06), DRR (0.25), R/S (-0.01),
CT 9993/MDU 5	70% RWC (0.41), DRR (0.18), R/S (0.001), PT (0.37), SF (-0.76)
CT 9993/ASD 18	R/S (0.01), PH (0.26), HI(0.02)
Moroberekan/MDU 5	70% RWC (-0.07), LD (0.54), RDW(0.11), R/S (0.01), PT (0.43), SF (-0.72)
Moroberekan/CO 47	LD (-0.11), R/S (-0.01), PT (0.30), GPP (1.54)
Nootripathu/MDU 5	LR (0.19), LD (0.04), DFF (0.64) PH (0.88)
Nootripathu/ASD 16	LR (-0.47), LD (0.04), DFF (-0.94)

consideration, among above 40 hybrids evaluated, only five hybrids viz., Moroberekan/MDU 5, CT 9993/MDU 5, Moroberekan/CO 47, Norungan/MDU5 and Nootripathu/MDU 5 were suitable for recombination breeding under water stress environments to get desirable segregants in early segregating generation.

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