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Trait effect in different days to flowering groups of rice cultivars as described by path analysis

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Abstract- Days to flowering determines some agronomic traits of rice cultivars. One agronomic trait of rice may effect on another trait in different degrees in yield determination. The quantitative effect of one agronomic trait on another trait is not constant in different days to flowering (DF) groups of rice. In the present study one hundred sixty-four rice cultivars with different days to flowering were grouped as 70- 80-, 90- and 100- days to flowering. Agronomic traits of 80 plants in 4 plots of individual rice cultivars were evaluated in field conditions. Path analysis was done to understand the effect of one trait on another trait in different DF groups of rice cultivars separately. It was found that effect of number of total tillers on number of fertile tillers and effect of number of total spikelets/panicle on number of fertile spikelets/panicle were equally higher in each DF group. Effect of bio mass, number of tillers, panicle length and number of spikelets/panicle on the final yield greatly varied with the DF groups. The negative effect of plant height on harvest index was also varied in DF groups. Effect of panicle length on panicle weight was exceptionally highest in the 80 DF group while the effect of bio mass weight on harvest index was highest in 90 DF group. It can be concluded that the effect of a trait on the yield and on other traits in rice change with the days to flowering of the rice cultivars.

Index Terms- Trait effect, days to flowering, traditional rice cultivars, Sri Lanka

INTRODUCTION

Transition of apical bud in to floral bud demarcates the initiation of reproductive stage of rice in its growth cycle. Number of days taken for this transition determines the heading date or days to flowering of any rice cultivar (Yano et al., 2001). Maturity of rice is said to be controlled by three different types of genes namely genes controlling photoperiod sensitivity, genes determining vegetative growth and genes deciding the total number of internodes (Li et al. 1995). These all types of genes determine the crop duration, crop architecture and the final grain yield of rice.

Final grain yield of rice is determined by the total effect of yield attributing traits including days to flowering. The changing pattern of total effect of traits in different days to flowering rice groups must be studied to understand whether the selection criteria of rice cultivars for breeding programs must be decided according to the days to flowering group of rice or not.

Among many agronomic characteristics, days to flowering, plant height and yield potential determine the economical production of any crop including rice (Xue et al. 2008). Plant height is the main determining factor of plant architecture which directly affect on the final yield. Other than the plant height number of tillers/plant, number of grains per panicle and grain weight also directly affect on the final yield of rice (Surek and Baser, 2003; Selvaraj et al. 2011; Babu et al. 2012).

Variation of days to flowering in rice shows its adaptation to different agro-climatalogical zones. Onset of monsoon rains, short day conditions, light intensity and temperature fluctuations are the considerable factors for selection of a rice cultivar for a said agro-climatological zone. Days to flowering in rice is determined by the length of basic vegetative growth phase and photo period sensitivity of the rice cultivar (Yano et al, 1997). Basic vegetative growth phase and days to flowering were controlled by many already identified genes such as Ef-1 and Se-1-Se-7 (Yakoo et al. 1980, Poonyarit et al. 1989). Genetic studies of rice have found that flowering time gene named Hd1 regulates days to flowering by inducing flowering in short-day conditions and inhibiting flowering in long day conditions (Lin et al. 2000). Different genes involved in flowering time in rice have reported in several studies (Yokoo et al. 1980; Yamagata et al., 1986; Okumoto and Tanisaka, 1997). This genetic differentiation has created a broad variation in days to flowering among rice cultivars. A quantitative trait loci named DTH8 was found to regulate yield, plant height and days to flowering in rice (Wei et al. 2010). There are several alleles of DTH8 and type 4, type 5, and type 6 alleles of DTH8 were studied by Wei et al. (2010). The results showed that all transgene-positive plants with type 4,-5, and-6 alleles of DTH8 were tall and late flowering with large panicles, whereas all transgene-negative plants have phenotypes with opposite features (Wei et al., 2010). This finding proves that tall and late flowering characters of rice inherit together if the late flowering is determined by DTH8.

Since panicles those start flowering earlier score higher filled grain percentages exhibiting higher sink efficiency than the panicles start flowering late in the season, the late flowering reduces dry matter accumulation in grains (Mohapatra et al. 1993). This emphasizes that the flowering date affects on the final grain yield of rice in a given season.

Effect of yield attributing traits on the final grain yield of rice has been extensively studied (Zahid et al. 2006; Prasad et al. 2001; Yang et al. 2007; Selvaraj et al. 2011). Effect of each trait in different days to flowering rice groups must yet to be revealed.

Traditional rice gene pool in Sri Lanka consists of more than 2000 accessions. Exploring this secondary gene pool is very important for identifying new genes for broadening the gene pool (Aggarwal et al. 2002; Brondani et al. 2006; Jayamani et al. 2007; Thomson et al. 2007). There is a wide variation of days to flowering in traditional rice gene pool in Sri Lanka. The present study was carried out to understand the trait effect of different days to flowering groups of traditional rice cultivars in Sri Lanka.

Path analysis partitions the total effect of the causal trait in to direct and indirect effect which is important for plant breeders to identify promising traits to be considered as a selection criterion of rice (Bhatti et al. 2005; Togay et al. 2008; Ali et al. 2009). In this study path analysis was carried out to understand the effect of a trait on another trait in rice in different days to flowering groups.

MATERIALS AND METHODS

One hundred sixty four traditional rice genotypes (Table 1) collected from Plant Genetic Resources Center (PGRC), Gannoruwa, Sri Lanka were geminated and planted in nursery beds. Two week old seedlings were transplanted in the experimental field at the Faculty of Agriculture, Mapalana, Kamburupitiya, Sri Lanka according to a complete randomized block design with four replicates. Each replicate consisted of three lines and each line consisted of twenty seedlings with 15 cm X 20 cm spacing. Proper weed and pest management strategies were followed during the cropping season and the field was properly covered by a birds' nest to minimize the bird attack on the yield.

Table 1 Days to flowering of studied rice genotypes

Acc. No.	Name	Acc. No.	Name
3416	*A 6-10-37*	3613	*Lumbini*
3482	*Akuramboda*	3718	*Mada Thawal*
3611	*Bala Kaharamana*	3650	*Madabaru*
3598	*Bala Ma wee*	3570	*Madael*
3496	*Bala Ma wee*	3508	*Madael Galle*
3651	*Balakara*	3514	*Madael Kalutara*
3550	*Bathkiri el*	3670	*Madoluwa*
3415	*BG 34-8*	3662	*Mah Sudu Wee*
3409	*BG 35-2*	3511	*Maha Murunga Badulla*
3410	*BG 35-7*	3721	*Manamalaya*
3652	*Buruma Thavalu*	3519	*Manchel Perunel*
3606	*Chinnapodiyan*	2349	*Mas Samba*
3131	*Dahanala 2014*	3435	*Matara wee*
3726	*Dandumara*	3214	*Matholuwa*
3681	*Dandumara*	3506	*MI 329*
3676	*Dena wee*	3571	*Miti Riyan*
3407	*Dewaraddiri*	3591	*Mudukiriel*
3687	*Dewaredderi*	3438	*Murunga wee*
3146	*Dewaredderi 26081*	3490	*Murungakayan 101*
3504	*Dik wee 328*	3489	*Murungakayan 3*
3567	*Dingiri Menika*	3394	*Muthu Samba*
3882	*Dostara Heenati*	3645	*Muthumanikam*
3383	*EAT Samba*	3427	*Naudu wee*
3589	*Gangala*	3136	*Pachchaiperumal 2462-11*
3498	*Geeraga Samba*	3487	*Palasithari 601*
3423	*Giress*	6863	*Papaku*
4726	*Gonabaru*	3417	*Periamorungan*
3691	*Gunaratna*	3395	*Podi sudu wee*
3518	*H 10*	3666	*Podisayam*
3451	*Halabewa*	3573	*Pokkali*
3688	*Handiran*	3654	*Pokuru Samba*
3641	*Heendik wee*	3639	*Polayal*
3610	*Heendikki*	3661	*Polayal*
3588	*Heenpodi wee*	3639	*Polayal*
3677	*Herath Banda*	3071	*Polayal*
3678	*Hondarawala*	3486	*Puwakmalata Samba*
3646	*Induru Karayal*	3669	*Rajes*

3658	*Ingrisi wee*	3668	*Ranruwan*
3616	*Jamis wee*	3655	*Rata wee*
3612	*Jamis wee*	4178	*Rathumadilla*
3595	*Kaharamana*	3517	*Seeraga Samba Batticaloa*
3440	*Kaharamana*	3516	*Seevalee Ratnapura*
3642	*Kahata Samba*	3614	*Sinnanayam*
4834	*Kallurundoivellai*	3497	*Sinnanayan 398*
3647	*Kalu gires*	3389	*Sivappu Paleusithri*
3653	*Kalu Karayal*	3477	*Sudu Goda wee*
3673	*Kaluhandiran*	3665	*Sudu Karayal*
3713	*Kalukanda*	3510	*Sudu wee Ratnapura*
3734	*Kanni Murunga*	3469	*Sudu wee*
3447	*Karabewa*	3397	*Suduheenati*
3463	*Karayal*	3660	*Suduru*
3686	*Karayal*	3572	*Suduru Samba*
3480	*Karayal*	3594	*Suduru Samba*
3607	*Kiri Murunga wee*	3671	*Suduru Samba*
3479	*Kiri Naran*	3698	*Surumaniyan*
3674	*Kirikara*	3507	*Suwanda Samba*
3720	*Kirikara*	3562	*Thunmar Hamara*
3434	*Kokuvellai*	3664	*Tissa wee*
4841	*Koopon Sivappu*	3160	*Valihandiran*
3675	*Kotathavalu*	4819	*Vellainellu*
3659	*Kotathavalu*	3401	*Wanni Heenati*
3679	*Kottakaram*	3735	*Weli Handiran*
3982	*Kuru Wee*	3615	*Yakada wee*
3656	*Kuruluthudu*	3445	*Yakada wee*
3638	*Lumbini*	3756	

Data were collected in 80 plants of four replicates. Data on plant height (cm), number of tillers/plant, number of fertile tillers/plant, panicle length (cm), panicle weight (g), number of spikelets/panicle, number of fertile spikelets/panicle, 100 grain weight (g) and yield/plant (g) and days to 50% flowering were recorded during the experiment. Total effect of yield attributing traits on grain yield was estimated by total effect dissected by Path analysis. Path analysis was performed using IBM SPSS AMOS statistical software (SPSS Inc., 2011). The changing pattern of effect of one trait on another trait with days to flowering was described by an equation with the R^2 using the most fitted line for the two variables.

RESULTS AND DISCUSSION

Days to flowering of rice cultivars given in table 1 was evaluated at the field conditions when the flowering of the individual rice cultivars reached at 50%. The days to flowering of rice cultivars varied from 78-107. The average values of 80 rice plants on ten different agronomic traits were used for path analysis of different days to flowering groups of rice (Table 2). The effect of individual trait dissected by the path analysis is given in table 2. The changing pattern of total trait effect as analysed by SPSS AMOS in different days to flowering group is given in table 3.

Effect of days to flowering on plant height:

The maximum effect of days to flowering on plant height was recorded in 70 DF group while it was gradually reduced up to 90 DF (Table 2). Only at 90 DF the effect of days to flowering on plant height was negative (Table 2A). It can be concluded that in 70 DF, 80 DF, and in 100 DF cultivars, days to flowering positively affects on the plant height but not in the 90 DF cultivars. However it has been reported an interaction between heading date and plant height (Yu et al. 2002). Some specific genes delay heading and increase plant height and panicle size (Xue et al. 2008). Though agronomic characters of rice is largely controlled by environmental factors, the plant height is least affected by the environment (Hittalmani et al. 2003). Hence the changes in effect of days to flowering on plant height with days to flowering must be due to the genetic differentiation in rice. This relationship can be explained by the equation $y = -0.27\ln(x) + 0.406$ (R^2=0.022).

Effect of plant height on number of tillers:

Tiller number of rice directly affects on the final grain yield capacity. A significant negative correlation in between plant height and tiller number was reported by Yang et al. (2006). Present study showed a sigmoid relationship in between plant height and tiller number with a minimum and a maximum value at 80 DF and 90 DF respectively (Table 3B). Tiller number per plant is a quantitative trait with a relatively low heritability (Xiong 1992). Hence the number of tillers are affected by the environment greatly.

Effect of number of tillers on number on fertile tillers:
Interestingly the number of tillers equally affects on number of fertile tillers from 70 DF to 90 DF but this effect was little reduced in the 100 DF group (Table 3C). Though tiller number per plant determines the panicle number per plant (Lie et al. 200) determination of number of fertile tillers is not greatly affected by days to flowering in rice.

Effect of plant height on panicle length:
According to the path analysis the maximum effect of plant height on the panicle length was recorded at the 100 DF group (Tabel 3D). Though it has been reported that plant height and panicles/plant had high positive indirect effect on yield/plant (Chakraborty et al. 2010), there was no records on total effect of plant height on panicle length.

Effect of number of fertile tillers on filled grain percentage:
This is a parabolic relationship with higher values at 70 DF group and 100 DF group (Table 3E). Spike number is closely related to rice tillering (Xue et al., 2008). Therefore, reducing productive tillers may affect on improving rice grain filling in 80 DF and 90 DF group.

Effect of plant height on harvest index and bio mass:
There was a positive effect of plant height on harvest index in 70 DF group, while this became negative in 100 DF group (Table 3F). It is obvious that the harvest index has an inverse relationship with the plant height as the plant height directly affects on the above ground bio mass. The minimum effect of plant height on bio mass was at 80 DF group while it was maximum at 100 DF group (Table 3G). This must be due to long vegetative growth phase which accumulates dry matter weight in the rice plant in 100 DF group. Mao et al. (2005) observed that QTLs which have pleotropic effects on yield and/or yield related traits. Dissection of genetic relationship of plant height, yield and bio mass is complicated when the pleotropic QTLs control the effect.

Effect of filled grain percentage on hundred grain weight:
There was a negative effect of filled grain percentage on hundred grain weight in 70 DF group to 90 DF group (Figure 3H). This might be the reason that the filling during short period of time leads incomplete grain filling without reaching spikelets' maximum weight. However, Jeng et al. (2006) showed a rapid filling rate even in a shorter grain-filling period in cultivar SA419.

Effect of panicle length on panicle weight:
Effect panicle length on panicle weight was maximum at 80 DF group while this was negative in 100 DF group (Table 3I). This explains that in 80 DF cultivars long panicles increase the panicle weight but in 100 DF cultivars, the long panicles do not increase the panicle weight. Failure in increasing filled grain percentage with the panicle length would be the reason for this. Jeng et al. (2006) has extensively studied the effect of panicle structure on the grain filling of rice where they reported that the even within a panicle the amount of grain filling differs with the place to where the spikelet is attached in the panicle.

Table 2. Trait effect of different days to flowering groups of rice

70 DF				80 DF				90 DF				100 DF			
PH	<---	DF	**0.474**	PH	<---	DF	0.151	PH	<---	DF	-0.06	PH	<---	DF	0.192
NT	<---	PH	0.136	NT	<---	PH	-0.479	NT	<---	PH	**0.34**	NT	<---	PH	0.073
NFT	<---	NT	**0.938**	NFT	<---	NT	0.933	NFT	<---	NT	0.93	NFT	<---	NT	0.808
PL	<---	PH	0.116	PL	<---	PH	-0.19	PL	<---	PH	0.19	PL	<---	PH	**0.429**
FGP	<---	NFT	0.506	FGP	<---	NFT	0.255	FGP	<---	NFT	0.17	FGP	<---	NFT	**0.563**
HI	<---	PH	**-0.225**	HI	<---	PH	-0.475	HI	<---	PH	-0.41	HI	<---	PH	-0.842
BM	<---	PH	0.306	BM	<---	PH	**0.198**	BM	<---	PH	0.47	BM	<---	PH	0.68
HGW	<---	FGP	-0.99	HGW	<---	FGP	-0.946	HGW	<---	FGP	-0.83	HGW	<---	FGP	0.439
PW	<---	PL	0.041	PW	<---	PL	0.682	PW	<---	PL	0.26	PW	<---	PL	-0.038
YLD	<---	PL	**0.417**	YLD	<---	PL	0.217	YLD	<---	PL	0.08	YLD	<---	PL	0.143
YLD	<---	NFT	-0.367	YLD	<---	NFT	0.262	YLD	<---	NFT	-0.22	YLD	<---	NFT	**0.438**
YLD	<---	BM	0.532	YLD	<---	BM	0.379	YLD	<---	BM	**0.7**	YLD	<---	BM	0.4

YLD	<---	DF	-0.381	YLD	<---	DF	**0.224**	YLD	<---	DF	0.01	YLD	<---	DF	-0.048
YLD	<---	NT	**0.507**	YLD	<---	NT	0.026	YLD	<---	NT	0.25	YLD	<---	NT	-0.31
YLD	<---	NS	0.263	YLD	<---	NS	**0.358**	YLD	<---	NS	-0.21	YLD	<---	NS	1.11

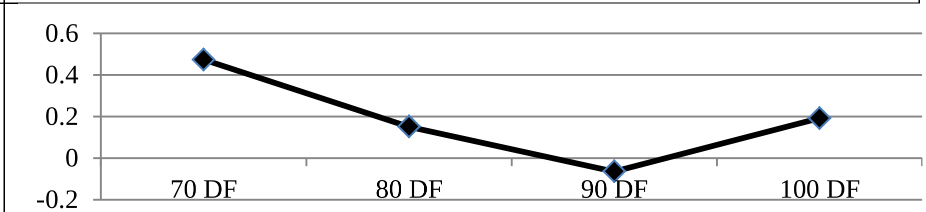
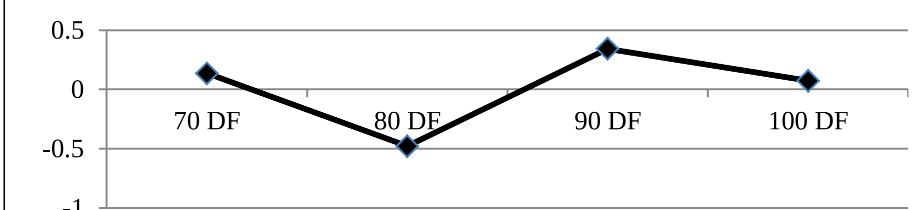
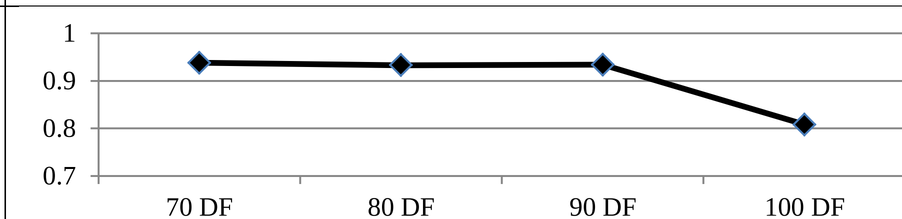
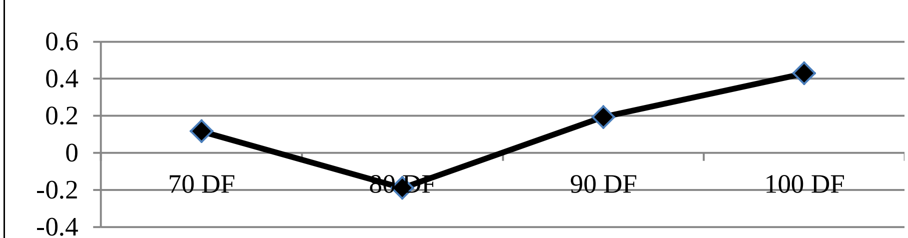
DF:Days to flowering, PH: Plant height, NT: Number of total tillers, NFT: Number of fertile tillers, PL: Panicle length, FGP: Filled grain percentage, HI: Harvest index, BM:Bio mass, NS:Number of spekelets, HGW:hundred grain weight, YLD:yield/plant, PW: panicle weight

The changing pattern of trait effect in rice with days to flowering is given in table 3.

Effect of different traits on yield:

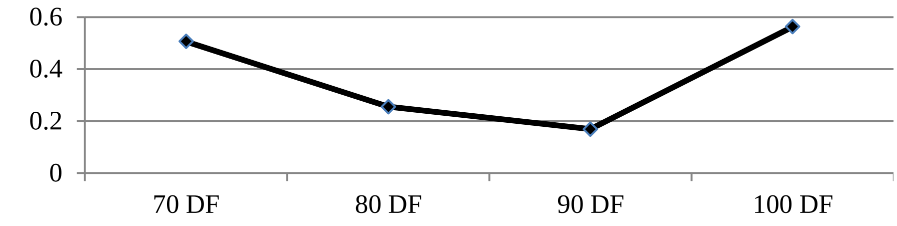
The maximum effect of panicle length and number of tillers on final grain yield was recorded at 70 DF group while the maximum effect of DF and number of total tillers were recorded in 80 DF group (Table 2). Only the trait bio mass recorded the maximum effect on the final grain yield in 90 DF group while number of fertile tillers recorded the maximum effect on yield in 100 DF group (Table 2, Table 3J-Table 3O). The collective effect of these all traits must be considered in each DF group to come to a conclusion to decide which parameters must be considered as selection criteria in different DF groups in rice.

Table 3 Changing pattern of trait effects in different DF groups

Trait effect Eg; Effect of Days to flowering on plant height (PH <---DF)	Changing pattern of trait effect in different days to flowering (DF) groups of rice. The equation for the relationship between days to flowering and trait is given with the R^2 value in each graph.
A. PH<---DF *$y = -0.27\ln(x) + 0.406$ R2=0.022	
B. NT<---PH *$y = 0.086x^2 - 0.368x + 0.291$ $R^2 = 0.134$	
C. NFT<---NT *$y = -0.07\ln(x) + 0.960$ $R^2 = 0.459$	
D. PL<---PH *$y = 0.221\ln(x) - 0.038$ $R^2 = 0.270$	

E.
FGP<---NFT

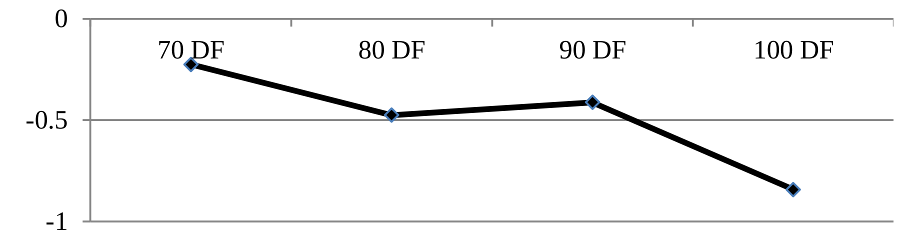
*$y = 0.340e^{-0.00x}$
$R^2 = 0.000$



F.
HI<---PH

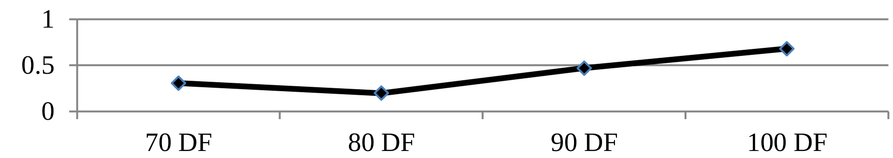
*$y = 0.086x^2 - 0.368x + 0.291$

$R^2 = 0.134$



G.
BM<---PH
*$y = 0.221\ln(x) - 0.038$

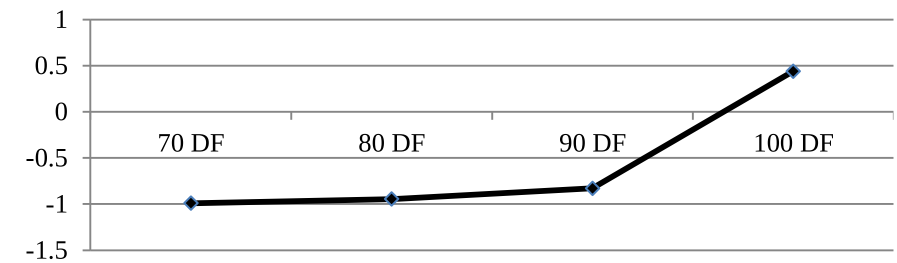
$R^2 = 0.270$



H.
HGW<---FGP

*$y = 0.340e^{-0.00x}$

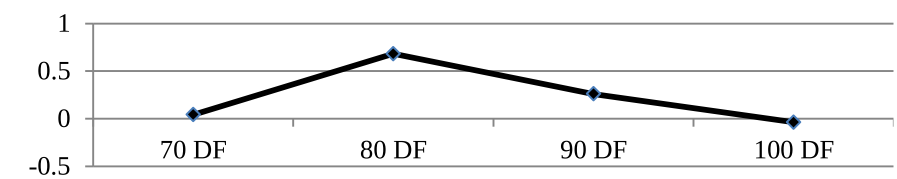
$R^2 = 0.000$



I.
PW<---PL

*$y = 0.078x - 0.245$

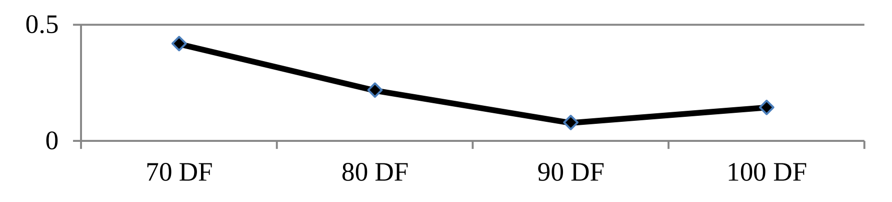
$R^2 = 0.163$



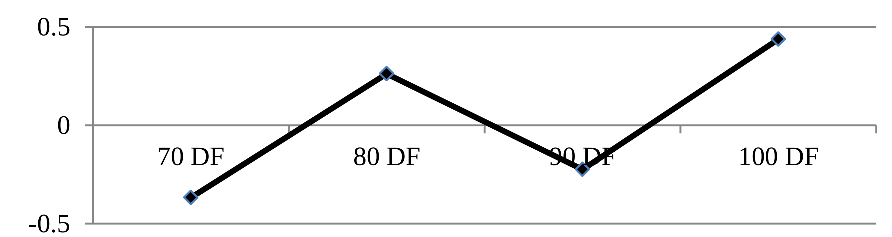
J.
YLD<---PL

*$y = 0.820\ln(x) - 1.233$

$R^2 = 0.520$

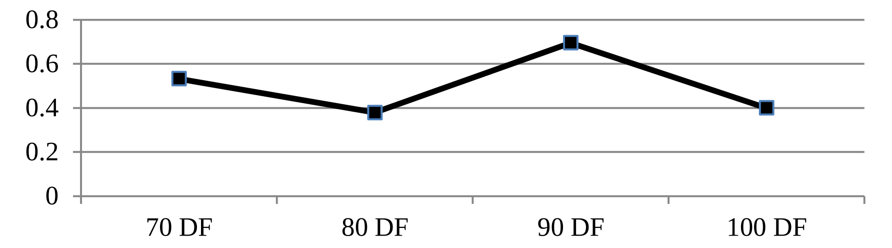


K.
YLD<---NFT
*$y = 0.008x2 + 0.151x - 0.413$
$R^2 = 0.421$

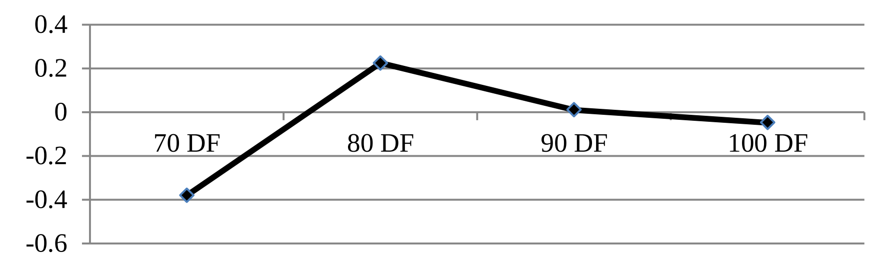


L.

YLD<---BM
*$y = -0.01\ln(x) + 0.511$
$R^2 = 0.002$

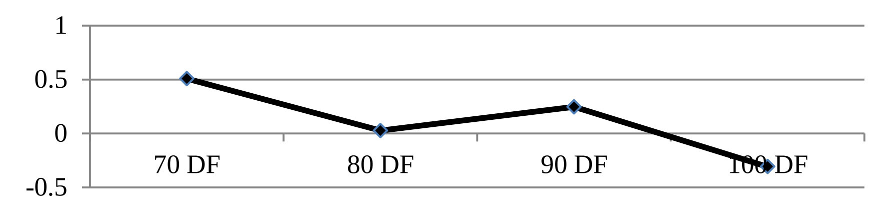


M.
YLD<---DF
*$y = 0.078x - 0.245$
$R^2 = 0.163$

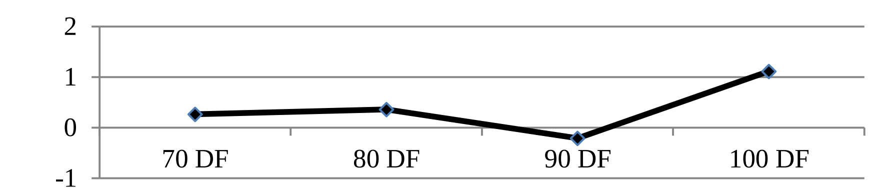


N.
YLD<---NT

*$y = -0.01\ln(x) + 0.511$
$R^2 = 0.002$



O.
YLD<---NS
*$y = 0.320\ln(x) + 0.125$
$R^2 = 0.123$



*The equation of the most fitted line which explains the changing pattern of the trait effect with the DF

CONCLUSIONS

Days to flowering positively affected on the plant height in 70 DF, 80 DF, and 100 DF cultivars but not in 90 DF cultivars. There was a sigmoid relationship in effect of plant height on tiller number in different DF groups. However, days to flowering did not greatly affect on number of fertile tillers in rice. At 100 DF group, plant height affected on the panicle length in its maximum capacity. In 80 DF and in 90 DF groups, fertile tillers weakly affected on filled grain percentage than that of in 70 DF and 100 DF group where the effect was prominent. Plant height in 100 DF group affect on bio mass greatly than that of in other DF groups. Hundred-grain-weight was negatively affected on filled grain percentage in 70 DF, 80 DF and in 90 DF groups but not in 100 DF group.

In 70 DF group, panicle length and number of tillers effected on the final yield greatly than those of in the other DF groups. In 80 DF group, the maximum effect of DF and number of total tillers on the final grain yield were prominent. The only trait which recorded the maximum effect on the final yield in 90 DF group was the bio mass while in 100 DF group, number of fertile tillers affected on the final grain yield greatly than that of in other DF groups. The collective effect of these all traits must be considered in each DF group to come to a conclusion to decide which parameters must be considered as selection criteria in different DF groups in rice.

Studying the effect of different traits of rice in different days to flowering groups is of great significance in breeding higher-yielding rice varieties in future, using improved techniques. Findings of trait effect in different DF groups in rice may help for such studies in future.

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