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Multivariate statistical analysis of cold season wheat yield under drought conditions

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Abstract:

Effect of drought stress on cold season wheat varieties investigated at Jolgeh-rokh station of Torbat Heydarieh agricultural and resources research center during 2012 and 2013. The experiment contained 18 inbred lines and promised varieties studied in optimal and limited irrigation levels. Two separate complete randomized block designs with three replications were carried out. At limited irrigation level plants did not irrigated at dough stage and physiological maturity stage. Measured treats was: plant height, spike length, peduncle length, grains/spike, grain weight, thousand grain weight, spike weight, harvest index, grain and biological yield. Results showed that Cold wheat 14 was the best variety in both irrigation levels. Grain yield significantly correlated with grain yield and biological yield at optimal condition. There was a positive correlation between biological yield peduncle weight and harvest index with grain yield at drought condition. Stepwise regression analysis showed that yield variation control by thousand grain weight, grains/spike and spike weight at optimal irrigation condition. Peduncle length was the only variable enters to regression model at drought condition. Peduncle length and weight had the highest indirect effect on yield as shown by path analysis. Factor analysis indicated that three factors accounted for about 80 percent of the total variation among characters. Investigating the drought susceptibility indices showed that mean productivity index and stress susceptibility index was the best in selecting tolerate varieties.

Keywords: bread wheat; late season drought; yield; drought susceptibility index.

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Introduction

Developing tolerate wheat cultivars under drought conditions is an important objective of breeding programs. It is necessary to investigate physiological mechanisms of stress tolerance to release genetically breed cultivars for drought condition (Abdmishani and Jafari, 1989; Blum, 1988). Studying genotype tolerance by comparing crop yield in optimal and stressful condition is a method to breed tolerant cultivars. It is assumed that yield and drought tolerance control by two different gene systems. Genes control crop reactions depending on environmental factors (Caramer et al, 1989, Fernandez, 1992 and Fischer, 2001).

Most of Iran wheat production areas suffer from drought and high temperature stress. Cereal production limited by these two stress factors, thus improving drought and high temperature tolerant cultivars is an important breeding plan in breeding programs (Levitte, 1972, Gol-abadi et al, 2009). Wheat growth and development, biological yield, grain development and fertility significantly affected by drought stress occurred before pollination. Source capacity limitation and thousand grain weight losses are the most important effects of after pollination drought (Ehdaie et al, 2008; Machado et al, 1993). Effect of drought stress is depending on physiological stage of wheat growth which stress happen on it. Grain and biological yield of wheat significantly decreases by drought stress (Doorenbos and Kassem, 1986, Muniri et al, 2007; Zare Feyzabadi ad Ghodsi, 2003; Gholami and Pour Asadollahi, 2008; Hamam, 2008).

Smith (1936) introduced selecting indices for first time and declared that varieties with high and stable yield in different environments are proper varieties (Dastfal and Ramezanpour, 2001; Blum, 1988; Cook et al, 1994). In other words the varieties with minimum yield variations between optimal and stressful conditions are favorite ones (Ehdaie, 1999).

Ahmadzadeh et al (2007), investigate share of different morphological characteristic of spring wheat in grain yield formation, applying factor analysis and stepwise regression. Grain yield was highly controlled by thousand grain weight, grain/spike, and green organ percent (Ahmadzadeh et al, 2007).

A trait will select as a drought tolerance agent if it is well defined, have a high heritability and its measuring is easy and accurate. High correlation between the trait and yield is important too (Naderi et al, 2004; Naderi and Mosharaf, 2001).

Tarinezhad (2001), declared that TOL, MP, STI and GMP are the best indices for selecting wheat hybrids in optimal and stressful conditions.

Other research carried out on 20 wheat genotype at optimize and stressful conditions. Result showed that MP, STI and GMP are the best indices for screening wheat genotypes tolerance to drought stress.

Effect of late season drought stress investigated on 6 wheat inbred lines. Pishtaz assumed as control variety. Results showed a significant different between grain yield, plant height and grain number of varieties in well irrigated and drought condition, but thousand grain weight and spike length did not affected by drought (Naderi and Mosharaf, 2001). Abdmishani and Jafari (1989) investigated the effect of drought stress on yield and yield components of 35 wheat varieties. They showed that grain yield, thousand grain weight, plant height, grain/spikelet and grain/ spike enhanced by spring irrigation. Significant correlation between grain yield in optimal and stressful condition showed that varieties with higher yield in optimal condition potentially could produce higher yield in drought condition (Abdmishani and Jafari, 1989). Khazaee (2003) stated that drought stress limited wheat grain and biological yield at Mashhad climatic conditions. The highest and lowest t grain yield belongs to Alvand and Navid respectively. Roshan yield was close to the Alvand in stressful condition. Biological yield significantly decreased by drought. Drought tolerant varieties like Alvand produced higher biological yield. Navid biological yield was 32% less than tolerant varieties (Khazaee, 2003).

Materials and methods

Two separate complete randomized block designs with three replications were carried out to investigate the effect of drought tolerance on 18 wheat inbred lines (table 1). Shahriar and Gascogen varieties planted as controls.

Table 1: paternal sources of investigated inbred lines

Line number	pedigree
1	Shahriar(Local control)
2	Gascogen(International control)
3	Jcam/Emu"s"//Dove"S"/3/Alvd/4/MV17/Attila
4	ES14/SITTA//AGRI/NAC
5	Mv17/5/Gds/4/Anza/3/Pi/Nar//Hys
6	Bkt/90-Zhong 87
7	Prl/90-Zhong 87
8	TORIK-16
9	Appolo/Hil 81A

10	Bkt/90-Zhong 87
11	TROCADERO
12	GANSU-6
13	1-66-76/Sub"S"
14	Ghk"S"/Bow"S"//Ning8201
15	MV17/3/Azd/Vee"S"//Seri82/Rsh/4/Azd/Vee#1//Attila
16	7C/CNO//CAL/3/YMH/4/VP...
17	CHAM4/TAM200//RSK/FKG15
18	Mv17//Attila/Bcn

One time in autumn and four times in spring irrigations performed to plants at optimal irrigation level. At drought treatment, plants not irrigated at dough stage and physiological maturity stage. At drought treatments, rain shelter applied during precipitations. A two year rotation field (cereal-fallow) select for experiment.

Filed ploughed, disk harrowed and finally flatted by land leveler.

Fertilizers applied base on soil analysis. Urea, ammonium phosphate and potassium sulfate used as (120-90-50) combination amount. Each genotype planted in 7.2m^2 (6×1.2) plots. Seed amount calculated base on thousand seed weight to receive final population of 450 plants in each square meter. Seeds disinfected by carboxin thiram against common bunt (Tilletia tritici). Weeds controlled by Granstar (20 gr ha^{-1}) and puma super (1 lit ha^{-1}) during tiller to stem emergence stages.

10 plants of each plot randomly selected to measuring plant height, spike length and peduncle length at the end of growing season. Then plants cuts above ground and grain/spike, grain weight and thousand grain weight accounted. Grain and biological yield measured by harvesting the central 6 m^2 of plot in each treatment.

STI, SSI, TOL and MP indices applied to select the proper genotypes in sin-stress and stressful conditions.

Data analyzed using SAS, MSTAT-C and SPSS software. Means compared by Duncan's multiple range test at 5 and 1% probability levels.

Results and discussions

The two year analysis of variance of two irrigation levels showed significant differences between genotypes in respect of measured traits (table 2,3). Significant difference between inbred lines showed existence of high diversity among them which is proper to screening drought tolerant inbred lines. Results of optimal irrigation level (table 2)showed a significant difference between genotypes in respect of grain/spike, thousand grain yield, biological yield, spike weight, peduncle length, spike length, plant height and grain yield at 1% probability level. Other traits showed difference at 5% probability level.

Table 2: results of measured traits analysis of variance at optima irrigation level

		Mean of squares										
SOV	df	Grain/spike	Grain weight	1000 grain weight	Biological yield	Spike weight	Peduncle weight	Harvest index	Plant height	Spike length	Peduncle length	Grain yield
Block	2	ns 33.305	ns 0.39	0.167ns	ns 0.017	ns 0.012	ns 0.001	0.002**	ns 0.048	ns 0.447	9.960**	25725.796ns
Genotype	17	145.810**	0.088*	47.956**	0.357**	0.225**	0.007*	0.001*	122.740**	1.261**	31.180**	445693.322**
Error	34	12.367	0.021	0.139	0.037	0.022	0.002	0.001	0.085	0.141	2.236	26544.757
C.V%		7.24	8.02	1.01	5.27	5.89	7.25	4.15	0.31	4.02	5.10	4.11

* and **: significant at 5 and 1 % probability levels and ns: not significant

Analysis of variance showed significant differences between genotypes in respect of measured traits at stress condition (table 3).

Table 2: results of measured traits analysis of variance at drought irrigation level

		Mean of squares										
SOV	df	Grain/spike	Grain weight	1000 grain weight	Biological yield	Spike weight	Peduncle weight	Harvest index	Plant height	Spike length	Peduncle length	Grain yield
Block	2	10.685 ns	0.035 *	0.118ns	0.051 ns	0.134 *	o.oo1 ns	o.oo1ns	0.185 ns	0.562 ns	5.523*	285221.167ns
Genotype	17	265.358**	0.096 **	15.424**	0.408 **	0.328 **	0.018 **	0.006**	106.252**	2.026 **	31.206**	822496.324**
Error	34	11.033	0.009	0.165	0.021	0.023	0.001	0.001	0. 01	0.165	1.019	166520.382
C.V%		6.31	6.44	1.41	4.55	6.73	6.35	5.84	0.35	4.35	3.28	12.71

* and **: significant at 5 and 1 % probability levels and ns: not significant

Grain weight, 1000 grain weight, biological yield, spike weight and grain yield decreased by drought (table 4, 5). Other researchers affirmed the same results about yield restriction in drought condition (Calderini et al, 1999; , Nachit et al, 1991; Richards et al, 2001). The highest grain yield belonged to genotypes number 14, 13 and 12 with 5347, 4477 and 4161 kg ha^{-1} production in optimal condition (table 4). The lowest grain yield produced by genotype number 10 with 3177 kg ha-1 yield. Genotypes number 13 and 14 were the proper genotypes at experiment environmental condition.

Table 4: comparison between means base on Duncan's at optima condition

Genotype no	Grain/spike	Grain weight	1000 grain weight	Biological yield	Spike weight	Peduncle weight	Harvest index	Plant height	Spike length	Peduncle length	Grain yield
1	40.50eg	1.70bc	41.22a	3.75cg	2.44ef	0.51fg	0.44f	98.44d	9.15ch	31.84cd	3635n
2	44.67cg	1.71bc	39.02d	3.35bg	2.29dg	0.47hi	0.51a	98.85cd	9.02dh	31.49ce	3994f
3	47.33af	1.79ac	37.42ef	3.83cd	2.57ad	0.50fh	0.47ce	73.44m	8.53gh	29.19df	3973h
4	52.67ac	2.02ab	37.85e	4.34ab	2.74ac	0.55de	0.46df	82.85l	9.73ad	30.47df	4067d
5	34.44ae	1.72bc	34.57h	3.73cg	2.47bf	0.57cd	0.46df	88.15j	10.10ac	29.32df	3473q
6	53.17ac	1.81ac	33.72i	3.79ce	2.58ad	0.45ij	0.48bd	89.77h	8.65fh	27.95ef	3985g
7	38.34g	1.56c	40.92ab	3.51cg	2.13eg	0.59bc	0.45ef	93.90g	9.03dh	34.89ac	3642m
8	34.39fg	1.66bc	41.62a	3.29fg	2.26dg	0.49gh	0.50ab	98.59d	9.35ag	36.67a	3660l
9	33.47af	1.67bc	34.95g	3.53cg	2.26dg	0.50fh	0.47ce	87.20k	8.89dh	26.84f	3533p
10	54.00ab	1.60c	29.64k	3.26g	2.01g	0.56ce	0.49ac	88.52ij	8.70eh	29.08df	3177r
11	43.17dg	1.55c	35.55g	3.30eg	2.10fg	0.44ij	0.47ce	93.47g	8.32h	31.87cd	3552o
12	52.34ac	2.00ab	37.82e	3.96bc	2.72ac	0.43j	0.50ab	94.70f	9.58af	30.50df	4477b
13	44.34cg	1.59c	35.47g	4.51a	2.37cg	0.65a	0.35g	95.92e	10.27a	32.00cd	4161c
14	54.67a	2.15a	40.24b	4.4ab	2.87a	0.61b	0.49ac	100.50b	9.90ad	34.59ac	5347a
15	45.50bg	1.82ac	39.68c	3.8cd	2.47bf	0.53ef	0.48bd	99.24c	9.63ae	37.12a	3832k
16	54.17ab	2.02ab	36.68f	4.32ab	2.78ab	0.55de	0.46ef	102.20a	10.15a	36.28ab	3967i
17	49.84ad	1.92ac	39.80cd	3.78cf	2.47bf	0.56ce	0.51a	89.00i	9.50af	32.73bd	3998e
18	56.00a	1.72bc	30.58j	3.75cg	2.51ae	0.44ij	0.46df	95.89e	9.28bg	29.75df	3934j

There was no significant difference between means with the same letters in each column

The highest and lowest grain yield belonged to genotypes no 14 (4211 kg ha^{-1}) and 7 (2229 kg ha^{-1}) at drought condition receptively (table 5). Genotypes no 13 and 14 showed the proper response in respect of measured traits. The lowest amount of measured traits belonged to genotypes no 7 and 11 in drought condition (table 5).

Table 5: comparison between means base on Duncan's at drought condition

Genotype no	Grain/spike	Grain weight	1000 grain weight	Biological yield	Spike weight	Peduncle weight	Harvest index	Plant height	Spike length	Peduncle length	Grain yield
1	45.50dh	1.49dg	35.15a	2.92eg	2.11df	0.51dg	0.51ab	94.18e	8.62df	31.87cf	2618p
2	47.84d	1.42fg	28.37e	3.04df	2.04df	0.52dg	0.47df	100.40a	9.23c	34.40ad	3166h
3	62.17b	1.69ae	26.65f	3.30bd	2.14df	0.51dg	0.52a	85.05k	8.27ef	29.02gi	3630c
4	61.50b	1.72ad	29.42cd	3.47bc	2.62b	0.53df	0.50ac	79.83m	9.30be	32.32be	3196f
5	73.33a	1.78a	25.98fg	3.60b	2.25ce	0.51dg	0.49bd	81.67l	9.43bd	27.04ij	2544q
6	65.00b	1.73ac	31.12b	3.34bd	2.42bd	0.54de	0.52a	87.30i	9.32bd	29.84fh	2877m
7	38.33h	1.12h	29.98c	2.42h	1.64g	0.44g	0.46eg	90.05g	8.42df	33.55bd	2229r
8	43.84eh	1.42fg	32.67a	2.86fg	1.99eg	0.50dg	0.50ac	6.40c	9.10de	36.40a	3097j
9	52.84cd	1.38fg	25.32g	2.94eg	2.04df	0.46eg	0.48ce	82.35l	8.85df	27.15ij	2904lc
10	59.50bc	1.50cg	20.36h	3.04df	2.01ef	0.52dg	0.50ac	86.55j	10.44a	28.44hi	2767n
11	45.83dh	1.26gh	28.48de	2.63gh	1.83fg	0.46eg	0.48ce	91.68f	8.05f	31.25dg	2748o
12	63.84b	1.75ab	29.24ce	3.52bc	2.56bc	0.49dg	0.49bd	91.75f	9.00df	29.67fh	3029k
13	43.00fh	1.31fh	28.64de	3.54bc	2.77ab	0.72a	0.37h	88.90h	10.79a	29.31gi	3906b
14	47.17dg	1.45fg	29.30ce	4.17a	3.01a	0.69ab	0.34i	96.54c	10.62a	33.10bd	4211a
15	47.33dg	1.47eg	30/05c	3.18cf	2.06df	0.45fg	0.47df	97.32b	9.13ce	34.23ac	3190g
16	52.00ce	1.49dg	28.2de	3.31bd	2.22ce	0.62bc	0.45fg	95.05d	8.88df	34.78ab	3590e
17	48.67df	1.52df	31.17b	3.23ce	2.23ce	0.56cd	0.48ce	93.82e	10.13ac	30.25eh	3610d
18	39.67gh	1.46eg	28.67de	3.43bc	2.70ab	0.66ab	0.44g	89.07h	10.27ab	25.19j	3122i

There was no significant difference between means with the same letters in each column

Plant height decreased by drought in both years (table 4, 5). Richards et al (2001), reported that plant height decreased by drought due to decrease in internodes. Diminished plant height results in lower biological yield. But the new dwarf genotypes are more tolerant to lodging and applying fertilizers (Reynolds et al, 2001; Richards et al, 2002).

Pearson correlation analysis performed to investigate the relationship between traits. Results showed that there was high correlation between grain weight and grain number with grain yield at optimal condition (table 6). Results were in agreement with Calderini et al (1999) Araus et al (2009).

Table 6: Pearson correlation coefficients at optimal condition

	Grain/spike	Grain weight	1000 grain weight	Biological yield	Spike weight	Peduncle weight	Harvest index	Plant height	Spike length	Peduncle length	Grain yield
Grain/spike	1										
Grain weight	0.710**	1									
1000 grain weight	-0.678**	0.021ns	1								
Biological yield	0.712**	0.832**	0.173ns	1							

Spike weight	0.663**	0.847**	-0.070ns	0.856**	1						
Peduncle weight	0.121ns	0.186ns	-0.006ns	0.355**	0.324*	1					
Harvest index	0.070ns	0.395**	0.333*	-0.171ns	0.062ns	-0.188ns	1				
Plant height	-0.171ns	0.097ns	0.370**	0.021ns	0.168ns	0.034ns	0,184ns	1			
Spike length	0.154ns	0.300**	0.100ns	0.533**	0.360**	0.288ns	0.336*	0.307*	1		
Peduncle length	-0.225ns	0,128ns	0.513**	0.002ns	0.107ns	0.127ns	0.231ns	0.630**	0.281*	1	
Grain yield	0.240ns	0.295*	0.066ns	0.516**	0.484**	0.380**	0.274*	0.283*	0.420**	0.520ns	1

There was no significant difference between means with the same letters in each column

Grain yield significantly correlated by biological yield, peduncle weight and spike weight at drought conditions (table 7). Results were in agreement with Haghparast and Sarbeze (1998). Other researchers showed that grain filling rate and grain weight decreased by drought which occurred after pollination (Motaghi, 2007; Noormand Moaied et a, 1999; Acreche and Slafer, 2009; Nachit et al, 1991; Robertson and Giunta, 1994).

Table 7: Pearson correlation coefficients at drought condition

	Grain/spike	Grain weight	1000 grain weight	Biological yield	Spike weight	Peduncle weight	Harvest index	Plant height	Spike length	Peduncle length	Grain yield
Grain/spike	1										
Grain weight	0.855**	1									
1000 grain weight	-0.613**	0.274*	1								
Biological yield	0.414**	0.572**	0.124ns	1							
Spike weight	0.214ns	0.363**	0.032ns	0.834**	1						
Peduncle weight	0.112ns	0.108ns	0.115ns	0.644**	0.713**	1					
Harvest index	0.518**	0.511**	0.191ns	-0.401**	0.433**	0.626**	1				
Plant height	-0.626**	0.395**	0.577**	0.113ns	0.084ns	0.185ns	-0.351**	1			
Spike length	0.007ns	0.059ns	0.075ns	0.576**	0.626**	0.694**	-0.501**	0.063ns	1		
Peduncle length	-0.464**	0.324*	0.577**	0.219ns	0.209ns	0.107ns	-0.208ns	0.535**	ns 0/233	1	
Grain yield	0.123ns	0.077ns	0.124*	0.637**	0.597**	0.691**	-0.554**	0.293*	0.458**	ns 0/119	1

There was no significant difference between means with the same letters in each column

Stepwise regression analysis considering the grain yield as the dependent variable and other characters as the independent variables showed that five traits account for about 76 percent of yield variations at optimal condition. The traits which enter the model were biological yield, plant height, grain weight, harvest index and spike weight respectively (table 8). Biological yield controlled more than 51 percent of yield variations. Thus the mentioned traits are proper to select genotypes in optimal irrigation conditions.

Table 8: stepwise regression coefficients at optimal condition

Variables	R	R^2adj	B	Beta	Se
Biological yield	0.516	0.252*	4.445	3.974	360.13444
Plant height	0.593	0.327*	2.417	0.324	341.61307
Grain weight	0.669	0.414**	-0.861	-4.217	318.66120
Harvest index	0.732	0.499**	2.927	2.004	294.80
Spike weight	0.764	0.540**	0.741	0.524	282.30829

* and **: significant at 5 and 1 % probability levels and ns: not significant

Three characteristics accounted for about 78 percent of grain yield. Peduncle weight accounted for more than 69 percent of grain yield. Peduncle weight seems to be proper in selecting high yield genotype in drought condition.

Table 9: stepwise regression coefficients at drought condition

Variables	R	R^2adj	B	Beta	Se
Peduncle weight	0.691	0.467**	1.459	0.544	355.49147
Biological yield	0.735	0.522**	0.802	0.630	336.73534
Grain weight	0.786	0.595**	-1.848	-0.365	309.8953

* and **: significant at 5 and 1 % probability levels and ns: not significant

Factor analysis is a multivariate statistical method for dwelling a wide range of data to a limited collection of factors. In this method data classifies to independent groups with high intergroup correlations. Three factors with eigenvalue one or more were found to control 73.9 percent of total variance (table 10). The first factor had the highest coefficient for grain number, biological yield, spike weight, spike length and grain yield. This factor the first factor may call the yield component factor. The second factor contained plant height and peduncle length and may be call the length factor. The third factor contained harvest index and may called harvest index factor (table 11).

Table 10: factor analysis coefficients at optimal condition

Variables	First factor	Second factor	Third factor
eigenvalue	3.97	2.45	1.7
Relative variance	0.361	0.223	0.155
Cumulative variance	0.361	0.584	0.739

Table 11: factor analysis at optimal condition

			Factors
Variables	First factor	Second factor	Third factor
Grain/spike	0.763	-0.474	0.301
Grain weight	0.849	0.099	0.484
Thousand grain weight	-0.218	0.810	0.098
Biological yield	0.935	-0.081	0.025
Spike weight	0.912	0.073	-0.172
Peduncle weight	0.427	-0.106	-0.381
Harvest index	0.061	0.317	0.872
Plant height	0.134	0.781	0.059
Spike length	0.546	0.327	0.468
Peduncle length	0.078	0.839	0.034
Grain yield	0.615	0.145	-0.452

Factor analysis at drought condition (table 12 and 13) showed that total variations controlled by three factors with eigenvalue one or more. These factors controlled 80.7 percent of total variations. First factor with high factor coefficient of biological yield, spike weight, peduncle weight, spike length and grain yield, may call yield components factor. The second factor contained thousand grain weight and spike length and may call plant architect factor. The third factor contained grain weight and may call grain factor.

Table 12: factor analysis coefficients at optimal condition

Variables	First factor	Second factor	Third factor
eigenvalue	4.067	3.580	1.211
Relative variance	0.371	0.326	0.110
Cumulative variance	0.372	0.697	0.807

Table 13: factor analysis at optimal condition

	Factors		
Variables	First factor	Second factor	Third factor
Grain/spike	0.072	-0.935	0.216
Grain weight	0.225	-0.786	0.551
Thousand grain weight	0.013	0.704	0.492
Biological yield	0.878	-0.317	0.221
Spike weight	0.886	-0.168	0.119
Peduncle weight	0.884	0.168	-0.104
Harvest index	-0.641	-0.568	0.336
Plant height	0.094	0.779	0.272
Spike length	0.784	0.001	-0.285
Peduncle length	-0.155	0.675	0.497
Grain yield	0.790	0.227	0/174

Fernandez (1992) classified plants according to their performance in stressful and stress free environments into four groups and introduced tolerate indices. Tolerate indices calculated for 29 wheat inbred lines and varieties (table 14). More tolerate genotypes base on each estimated index presented at table 14. Assumed STI, MP and GMP as the proper tolerance indices, genotype no 14 was the best line with high yield in both sin stress and stressful conditions.

Table 14: tolerant genotypes base on different tolerate indices

Tolerate index	Proper genotypes
Y_p	17-6-12-14
Y_s	7-12-14-13
TOL	11-17-18-10
MP	6-12-17-14
STI	2-6-13-14
GMP	6-17-14-12
SSI	8-18-14-11

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