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Per Se Performance and Selection Indices over Irrigated and Limited Irrigation Conditions in Coriander (*Coriandrum sativum* L.)

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Twenty five diverse genotypes of coriander (*Coriandrum sativum* L.) were tested in RBD with three replications during the *rabi* seasons in the year 2012-13 at instructional farm, Junagadh Agriculture University, Junagadh. The objective of the experiment was to construct efficient selection indices that could lead to high genetic advance for grain yield. The result indicated that all of the selection indices made up of a single trait were inefficient over direct selection for grain yield under both the situations. The relative efficiencies of selection indices constructed in combinations of two or more traits were ranged from 124.65 to 1824.33% and 176.71 to 1576.87% in irrigated and limited irrigation conditions, respectively. An index composed of plant height, umbels per plant, seeds per umbel and harvest index was the most efficient (1699.42%) under irrigated condition. The most efficient (1421.56%) selection index under limited irrigated condition was constructed by using seed yield, umbels per plant, seeds per umbel and harvest index. Direct selection for harvest index gave high genetic advance (10.43%) in irrigated condition while in limited irrigation condition seeds per umbel showed high genetic advance (8.52%) among all selected characters. Generally the use of selection index improved genetic advance over direct selection for grain yield under both water regimes. Construction and exploration of selection index in practical plant breeding is therefore important in coriander breeding programmes.

Key words: Coriander, *Coriandrum sativum*, Selection index, Genetic advance.

Among spices, coriander (*Coriandrum sativum* L.) is one of the important spice crop and one of the oldest spice. It is a cross pollinated diploid species, with 2n=22 chromosome. A pleasant aromatic odour is present in the stem, leaves and fruits of coriander, which is due to an essential oil containing mainly linalool or coriandrol (Pruthi, 1976). The young plant is used in preparing chutney and leaves are used for flavouring curries, soups and savouries. Dry fruits are extensively used in pickle preparation, curry powder seasoning and sausages. It is also considered to be carminative, diuretic, stomachachic, tonic, antibilious, refrigerant and aphrodisiac (Murty and Sridher, 2001).

Coriander (*Coriandrum sativum* L.) is an annual herb belonging to the family Apiaceae. The genus *Coriandrum* has two species, of which *Coriandrum sativum* is cultivated. Ivanova and Stoletova (1990) reported four subspecies within *Coriandrum sativum:* ssp. *Sativum, indicum, asiaticum* and *vavilovii*. Diederichsen (1996) conducted an extensive analysis of morphological variation, and on that basis proposed the following ecogeographic types: Near Eastern, Indian, Central Asian, Syrian, Caucasian and Ethiopian.

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The plant is a glabrous erect or semi-erect herb attaining 25 to 100 cm of height with lower leaves pinnate with sessile rounded leaflets having serrate margins and upper leaves are finally cut with linear lobes and are bi or tri-pinnate. The flowers are small, white or pink colored and borne in compound umbel. The flowers are hermaphrodite and staminate. Fruits are a schizocarp, globular in shape, yellow- brown colour when ripe and ribbed. The fruits consist of two halves, the single seeded mericarps. The unripe fruits smell of bed bugs and thus character is responsible for determination of the name coriander from the Greek world "Koris" meaning bed bug. The ripe fruits are pleasantly aromatic (Diederichsen, 1996).

Yield in crops is a quantitative trait and has a complex genetic control mechanism and direct selection is not much effective on it. The most desirable approach to improve characteristics such as seed yield is simultaneous selection based on related traits. This can be done by using selection index, which is multiple regressions of genotypic values on phenotypic values of several traits. The use of selection index is superior in improving complex traits. Furthermore, selection indices aimed at determining the most valuable genotypes as well as the most suitable combination of traits with the intention of indirectly improving the yield in different plants. Selection index has also been applied in improving cool season food legumes tolerance to biotic and abiotic stresses. In ground nut, Patra (1980) reported that selection index based on shelling percentage, number of mature and immature pods per plant was 6.68 times more efficient than direct selection based on yield alone in ground nut. The efficiency of selection index is measured based on the genetic progress that can be achieved using selection index as compared to the corresponding genetic gain to be attained using direct selection for grain yield alone as described by Allard, 1960. In this paper, efforts was made to apply selection index that combine the phenotypic and genotypic values of different yield components of coriander that could enhance the genetic improvement for yield.

MATERIALS AND METHODS

The experimental material comprised of twenty five promising genotypes of coriander (Table 1). The genotypes were obtained from the germplasm at the National Research Center on Seed Spices (ICAR), Tabji, Ajmer (Rajasthan). The trail was conducted in Randomized Block Design (RBD) with three replications in two conditions created by giving different levels of irrigation to the crop. Each entry was planted as a single row of 4.0 m length, keeping plant to plant distance of 10 cm and row to row spacing of 45 cm. The soil of experimental site was medium black, alluvial in origin and poor in organic matter. The climate of the area represents tropical condition with semiarid nature. The data were recorded on twelve characters *viz.*, days to 50% flowering, plant height, number of basal leaves, longest basal leaf length, number of fruit bearing branches, umbels per plant, umbellets per plant, seeds per umbel, seed yield per plant, 100-seed weight, days to maturity and harvest index. Except days to 50% flowering and days to maturity, were recorded on plot basis, data on rest of the characters was recorded on five randomly selected plants in all the three replications. The recommended package of practices was followed to raise a good crop.

Statistical Analysis

Application of discriminant function as a basis for making selection on several characters simultaneously is aimed at discriminating the desirable genotypes from undesirable ones on the basis of their phenotypic performance. Selection index was proposed for the first time by Smith (1936) on the basis of discriminant function of Fisher (1936). The model suggested by Robinson *et al.*, (1951) was used for the construction of selection indices and development of a required discriminant function. Smith (1936) defined the genetic worth (H) of an individual as:

$H = a_1G_1 + a_2G_2 + \ldots, a_nG_n$

Where,

$G_1, G_2, \ldots, G_n$ are the genotypic values of individual characters

a1,a2, …, an signify their relative economic importance

Another function (I), based on the phenotypic performance of various characters, was defined as:

$I = b_1p_1 + b_2p_2 + \ldots, b_np_n$.

Where,

$b_1, b_2, \ldots, b_n$ are to be estimated such that the correlation between H and I i.e. r(H,I) becomes maximum. The maximization of r(H,I) leads to a set of simultaneous equations which upon solving give the desired estimate of 'bi' values. Considering three characters as an example, the simultaneous equations look like as follows :

$b_1X_{11} + b_2X_{12} + b_3X_{13} = a_1G_{11} + a_2G_{12} + a_3G_{13}$
$b_1X_{21} + b_2X_{22} + b_3X_{23} = a_1G_{21} + a_2G_{22} + a_3G_{23}$
$b_1X_{31} + b_2X_{32} + b_3X_{33} = a_1G_{31} + a_2G_{32} + a_3G_{33}$

Which in matrix from become

$$\begin{bmatrix} X_{11} & X_{12} & X_{13} \\ X_{21} & X_{22} & X_{23} \\ X_{31} & X_{32} & X_{33} \end{bmatrix} . \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix} = \begin{bmatrix} G_{11} & G_{12} & G_{13} \\ G_{21} & G_{22} & G_{23} \\ G_{31} & G_{32} & G_{33} \end{bmatrix} . \begin{bmatrix} a_1 \\ a_2 \\ a_3 \end{bmatrix}$$

X b G a

Where, X = The phenotypic variance-co variance matrix, b = The discriminant function coefficient, G = The genotypic variance-co variance matrix, a = Economic weightage

The solution of these equations gives the estimate of 'bi' values in the following manner:

$$b = X^{-1}.G.a.$$

Where, X^{-1} = The inverse matrix of X, G = The genotypic variance-co variance matrix, a= Economic weightage

The mathematical description of the function (I) is known as selection index:

$$I = b_1p_1 + b_2p_2 + \ldots, + b_np_n$$

Using this function it is possible to discriminate among the superior and inferior plants or combination of characters. Selection index or score is calculated for all the plants or combinations of characters and those with the highest value are considered.

Expected genetic advance

The expected genetic advance through selection may be calculated by the following formula suggested by Robinson *et al.* (1951).

$$G = \frac{Z}{P} \frac{\sum\sum a_i b_i G_{ij}}{(\sum\sum b_i b_j P_{ij})^{1/2}}$$

Where, Z/P = The standardized selection differential (s) indicating the intensity of selection (i) at 5% i.e., k= 2.06, a_i = Economic weightage, b_i = The regression coefficient, G_{ij}=The genotypic variance-co variance matrix, P_{ij} =The phenotypic variance-co variance matrix

Relative efficiency

The Relative efficiency of different discriminant functions was calculated according to Roinson *et al.* (1951), assuming the efficiency of selection for seed yield as 100 %.

$$RI (\%) = \frac{GA (D)}{GA (S)} \times 100$$

Where, RI = Relative efficiency, GA (D) = Genetic advance through discriminant functions, GA(S) = Genetic advance through straight selection

RESULTS AND DISCUSSION

All selection indices built on single traits were inefficient over strait selection for seed yield alone. Twelve selection indices containing two or more traits simultaneously were constructed in each situation, irrigated and limited irrigation condition. All selection indices were most efficient than direct selection for seed yield under both the situations. The expected genetic advance and relative efficiencies of these selection indices were given (Table 3 and 4). Under irrigated condition, the relative efficiency of these indices were in the range of 994.374 to 1824.330% (Table 3). The highest genetic advance and relative efficiency were observed for selection index no.12 containing seed yield, plant height, number of fruit bearing branches, umbels per plant, seeds per umbel and harvest index. This index gave a 1824.330% relative efficiency over selection based on seed yield. Selection index no.9 made up of seed yield, plant height, number of fruit bearing branches and seeds per umbel was the least efficient, 782.472%. The low efficiency (26.368%) of selection index made of number of fruit bearing branches alone was remarkably improved (782.472%) when seed yield, plant height and harvest index were simultaneously included into selection index built on number of fruit bearing branches alone (Table 2 and 3). The efficiency of selection index based on plant height alone was improved considerably from 441.166 to 1186.389% due to the addition of harvest index to make index no.3; from 441.166 to 1434.352% due to addition of umbels per plant and harvest index to make index no.7 (Table 2 and 3). An addition of harvest index to index no.1 gave an index no.2, this index was 894.350% efficient over straight selection on seed yield. Selection index derived from number of fruit bearing branches was -73.632% efficient over selection for yield only. But increasing the length of this index by including seed yield, umbels per plant, seeds per umbel and harvest index; seed yield, plant height, umbels per plant, seeds per umbel and harvest index made the resulting index no.11 and 12, respectively. These indices, in that order were 1741.358 and 1824.330% efficient. However highest genetic advance (20.341) and efficiency (1824.330%) were attained when these traits were combined to make selection index no.12 (Table 3).

In limited irrigation condition, direct selection for yield alone brought about a genetic progress of 4.117%. Nine selection indices were more efficient than selection using seed yield under this condition. When seed yield was accompanied by harvest index to form index no.3, the genetic advance was increased to 9.590 % and the corresponding relative efficiency of an index was 1210.725%. The most efficient (1576.873%) selection index no.12 was constructed by using seed yield, plant height, number of fruit bearing branches, umbels per plant, seeds per umbel and harvest index (Table 4). An index based on number of fruit bearing branches (Table 2) was 99.148% efficient over direct selection for seed yield alone. However, when harvest index and seeds per umbel joined this index, the efficiency of the resulted index no.2 and index no.4, improved to 1136.446 and 1362.251% respectively, which was much efficient than direct selection. The efficiency of the resulted index no.3 (Table 4) was by far higher than an index made of either seed yield or harvest index (Table 2). The relative efficiency of the selection index made up of umbels per plant (Table 2) was enhanced to 1421.561% by adding seed yield, seeds per plant and harvest index in an index no.10 (Table 4). When seed yield, number of fruit bearing branches, umbels per plant, seeds per umbel and harvest index were used simultaneously; the resulting index no.11 was 1504.006% efficient over

Table 1. List of genotypes used in present study and their sources

Sr. No.	Name of genotype	Sources
1	GUJ. DHANA-2	JUNAGADH
2	CGL-1	JUNAGADH
3	CGL-2	JUNAGADH
4	CGL-3	JUNAGADH
5	IC-570325	NRC on Seed Spices Ajmer
6	MKSM-1059	NRC on Seed Spices Ajmer
7	HISARS	NRC on Seed Spices Ajmer
8	VDV/GL173	NRC on Seed Spices Ajmer
9	JCO-329	NRC on Seed Spices Ajmer
10	MKSM-1110	NRC on Seed Spices Ajmer
11	ACR-139	NRC on Seed Spices Ajmer
12	SINDHU	NRC on Seed Spices Ajmer
13	NDCOR-43	NRC on Seed Spices Ajmer
14	RCR-41	NRC on Seed Spices Ajmer
15	IC-146683	NRC on Seed Spices Ajmer
16	MKSM1111	NRC on Seed Spices Ajmer
17	VDV/GL-2	NRC on Seed Spices Ajmer
18	SKCV09-40	NRC on Seed Spices Ajmer
19	AUSTRALIA	NRC on Seed Spices Ajmer
20	UD-401	NRC on Seed Spices Ajmer
21	ACR-173	NRC on Seed Spices Ajmer
22	MKSM1116	NRC on Seed Spices Ajmer
23	MKSM1091	NRC on Seed Spices Ajmer
24	DHANA-139	NRC on Seed Spices Ajmer
25	ACR-13	NRC on Seed Spices Ajmer

Table 2. Expected genetic advance (G) and the relative efficiency of selection index (RESI %) of the six traits under irrigated and limited irrigation conditions

Index no.	Irrigated condition			Limited irrigation condition		
	Selection index	Genetic advance	RESI %	Selection index	Genetic advance	RESI %
1	0.770X1	1.115	100.000	0.684X1	4.117	100.000
2	0.466X2	4.919	441.166	0.550X2	1.244	573.722
3	0.218X3	0.294	26.368	0.434X3	3.409	99.148
4	0.843X4	6.619	593.632	0.434X4	3.439	405.256
5	0.749X5	5.564	499.013	0.516X5	8.524	451.847
6	0.633X6	10.431	935.516	0.517X6	4.310	1115.767

Where X1 - Seed yield, X2 - Plant height, X3 - Number of fruit bearing branches
X4 - Umbels per plant, X5 - Seeds per umbel, X6 - Harvest index

Table 3. Selection indices, expected genetic advance (G) and the relative efficiency (RESI %) over straight selection for seed yield under irrigated condition.

Index no.	Selection index	Genetic advance	RESI %
1	0.770X1 (seed yield alone)	1.115	100.000
2	1.070X1 + 0.611X6	11.087	994.374
3	0.577X2 + 0.684X6	13.228	1186.389
4	0.877X5 + 0.630X6	13.626	1222.101
5	0.979X4 + 0.644X6	13.873	1244.175
6	0.665X1 + 1.005X4 + 0.642X6	14.718	1320.013
7	0.598X2 + 0.971X4 + 0.694X6	15.993	1434.352
8	1.025X4 + 0.898X5 + 0.635X6	17.228	1545.086
9	2.073X1 + 0.439X2 + 0.790X3 + 0.641X5	8.725	782.472
10	0.569X2 + 1.024X4 + 0.830X5 + 0.695X6	18.949	1699.421
11	0.571X2 + 1.652X3 + 1.022X4 + 0.796X5 + 0.695X6	19.416	1741.358
12	1.481X1 + 0.575X2 + 1.809X3 + 0.984X4 + 0.769X5 + 0.653X6	20.341	1824.330

Where X1 - Seed yield, X2 - Plant height, X3 - Number of fruit bearing branches
X4 - Umbels per plant, X5 - Seeds per umbel, X6 - Harvest index

Table 4. Selection indices, expected genetic advance (G) and the relative efficiency (RESI %) over straight selection for seed yield under limited irrigation condition.

Index no.	Selection index	Genetic advance	RESI %
1	0.684X1 (seed yield alone)	4.117	100.000
2	0.742X3 + 0.520X6	5.136	1136.446
3	2.545X1 + 0.447X6	9.590	1210.725
4	5.026X3 + 0.650X5	4.167	1362.251
5	3.409X1 + 0.329X5 + 0.392X6	3.828	1234.497
6	2.740X1 + 0.417X3 + 0.443X6	8.091	1236.528
7	6.087X1 - 0.157X4 + 0.285X6	7.099	1293.619
8	4.353X1 - 4.240X2 + 4.434X3 + 0.632X6	3.924	557.413
9	5.851X1 + 1.083X3 - 0.147X4 + 0.297X6	9.479	1346.456
10	6.165X1 - 0.060X4 + 0.604X5 + 0.265X6	10.008	1421.561
11	5.757X1 + 1.430X3 - 0.064X4 + 0.614X5 + 0.284X6	10.588	1504.006
12	7.228X1 - 0.027X2 + 2.041X3 -0.376X4 + 0.686X5 + 0.216X6	11.101	1576.873

Where X1 - Seed yield, X2 - Plant height, X3 - Number of fruit bearing branches
X4 - Umbels per plant, X5 - Seeds per umbel, X6 - Harvest index

Table 5. Heritability and Genetic advance as per cent of mean under irrigated and limited irrigation condition

Sr. no.	Traits	Heritability		Genetic advance as per cent of mean	
		Irrigated condition	Limited irrigation condition	Irrigated condition	Limited irrigation condition
1	Seed yield	77.02	68.36	66.07	45.19
2	Plant height	46.62	54.95	10.93	10.58
3	Number of fruit bearing branches	21.78	43.40	5.65	15.13
4	Umbels per plant	84.28	43.37	42.47	19.97
5	Seeds per umbel	74.93	51.61	24.42	13.91
6	Harvest index	63.34	51.68	36.98	25.53

Table 6. Comparative *per se* performance of coriander genotypes under irrigated and limited irrigation condition for characters studied for selection indices.

S. N.	Genotypes	Seed yield per plant (g)		Plant height (cm)		No. of fruit bearing branches		Umbels per plant		Seeds per umbel		Harvest index	
		Irrigated	Limited	Irrigated	Limited	Irrigated	Limited	Irrigated	Limited	Irrigated	Limited	Irrigated	Limited
1	GUJ. DHANA-2	2.23	1.60	43.20	35.67	4.67	3.40	15.33	13.40	19.33	21.00	32.62	39.10
2	CGL-1	2.07	1.70	44.43	37.20	4.83	3.07	19.13	13.00	23.47	22.00	37.33	33.82
3	CGL-2	1.87	1.80	58.33	37.27	5.47	3.80	12.73	13.93	23.53	24.07	34.03	34.92
4	CGL-3	2.07	1.30	50.00	46.67	5.07	4.67	12.53	12.53	21.60	21.43	30.48	33.10
5	IC-570325	1.50	1.27	42.60	37.20	5.67	4.60	12.40	11.40	24.47	23.60	39.49	36.41
6	MKSM-1059	1.53	1.63	42.07	36.20	5.20	4.33	14.13	14.80	23.27	20.50	21.35	32.64
7	HISARS	1.67	1.67	43.67	34.27	5.53	4.87	13.87	20.93	19.07	24.47	32.28	26.18
8	VDV/GL173	1.03	1.43	42.07	32.67	5.53	4.27	18.40	15.73	21.73	24.27	34.13	25.63
9	JCO-329	2.07	1.67	45.27	38.33	4.80	4.47	12.80	9.40	23.00	16.60	35.63	37.39
10	MKSM-1110	1.07	1.60	41.73	36.53	4.80	4.93	10.73	14.53	24.40	24.97	22.02	37.30
11	ACR-139	3.90	2.57	45.47	41.07	5.67	4.93	25.87	15.27	28.40	27.00	34.52	41.25
12	SINDHU	0.90	1.10	45.27	42.67	4.07	4.27	14.47	14.07	15.87	23.93	20.88	20.79
13	NDCOR-43	1.27	2.57	47.17	37.73	5.27	5.80	15.07	19.60	18.13	25.07	19.46	33.76
14	RCR-41	2.30	2.17	46.20	41.40	4.87	5.00	20.20	15.40	21.47	21.27	37.62	27.49
15	IC-146683	1.87	0.80	46.13	39.67	6.13	4.00	13.33	13.87	25.73	26.20	32.69	18.14
16	MKSM1111	1.07	1.27	43.33	38.17	5.40	4.67	16.87	11.40	20.40	23.20	19.37	28.15
17	VDV/GL-2	0.97	1.00	49.67	37.93	5.40	4.73	13.20	13.33	21.47	23.77	21.32	20.37
18	SKCV09-40	1.87	1.23	42.40	34.13	5.40	4.33	19.67	11.40	19.60	18.73	24.01	25.45
19	AUSTRALIA	1.60	1.90	41.20	40.53	5.07	5.40	12.93	16.53	20.93	26.40	21.91	31.19
20	UD-401	1.03	1.70	42.23	38.13	4.73	4.80	14.13	14.80	26.40	22.97	19.66	29.08
21	ACR-173	1.20	1.10	48.27	38.67	4.60	4.73	12.93	11.13	21.80	21.00	21.25	25.61
22	MKSM1116	1.10	1.27	37.73	36.93	5.60	5.53	18.20	14.33	22.53	25.13	20.80	31.47
23	MKSM1091	1.87	1.97	43.93	41.47	5.60	5.27	15.60	15.07	26.00	21.80	34.39	33.89
24	DHANA-139	2.07	1.47	42.27	37.60	5.07	4.80	13.13	15.20	27.87	21.60	32.24	37.07
25	ACR-13	2.10	1.17	50.53	36.13	5.53	4.60	22.00	16.00	29.27	20.67	25.81	28.88
	Mean	1.69	1.56	45.01	38.17	5.20	4.61	15.59	14.28	22.79	22.87	28.21	30.76
	CV %	19.96	18.05	8.32	6.27	11.14	12.79	9.70	16.82	7.92	9.10	17.16	16.67
	CD 5%	0.55	0.46	6.14	3.93	0.95	0.97	2.48	3.94	2.96	3.42	7.95	8.42

straight selection for seed yield. But neither of these traits is efficient when used individually (Table 1). Selection index made up of the same single trait did not show similar efficiency under both the situations (Table 2). Direct selection for seed yield, index no.1 did not have the same genetic advance under both the conditions. Selection based on seed yield alone gave higher genetic advance under limited irrigation condition (4.117%) than irrigation condition (1.115%). However, no selection indices containing more than one trait were common to both the water regimes.

The plant breeder has certain desired plant characteristics in his mind while selecting for particular genotypes and for this he applies various weights to different traits for arriving on decisions. This suggests the use of selection index which gives proper weight to each of the two or more character to be considered. Hazel and Lush (1943) showed that the selection based on such an index is more efficient than selecting individually for the various characters. The basis for the development of the selection indices has been provided by Smith (1936), Hazel (1943) and Robinson *et al*. (1951).

The reported genetic advance and relative efficiency of selection indices in coriander clearly showing the potential of selection index in coriander breeding programme. Selection indices containing single trait are not efficient to bring genetic improvement coriander for yield. This is due to the fact that yield is a commutative effect of several trait is not expected to explain fully the genotypic variation for yield. Yadav and Singh (1988), Hussain *et al*. (2003) in mustard, Chaudhary *et al.* (1996) in clusterbean and Sodavadiya *et al*. (2012) in pigeonpea were also with the same opinion that an increase in characters resulted in an increase in genetic gain and that the selection indices improve the efficiency than the straight selection for yield alone. However, it is believed that when two or more single-trait based indices are merged, the relative efficiency of the resulted index is better than using each of the single traits independently. Singh and Baghel (1977) reported that in sorghum, direct selection for grain yield per plant has been as efficient as an index containing grain yield per plant, number of grains per panicle, 1000 grain weight and number of primary branches per panicle. However, neither of these yield components has been efficient when used individually.

Comparative *per se* performance of coriander genotypes under irrigated and limited irrigation condition for characters studied for selection indices are given in Table 6.

For distinct perfect indices to selecting the best genotype and calculating relative efficiency, broad heritability and genetic advance as per cent of mean for all the characters which have been selected to calculate selection indices are shown in Table 5.

CONCLUSION

The reliability of selection index greatly depends up on the data quality and accuracy of variance and covariance estimates. The estimates being specific to breeding population. The finding of this research indicated that the use of selection indices is more efficient than direct selection for grain yield alone. However, identifying the best possible combinations using traits that are easily measurable with greater precision and best estimation of phenotypic and genotypic variance-covariance parameters are important to optimize selection index.

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