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The Estimation of Combining Ability and Heterosis Effect for Yield and Yield Components in Tomato (*Solanum lycopersicum* Mill.) at Lowland

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ABSTRACT

A study was conducted in a 6 × 6 full diallel cross set of tomato including reciprocals to estimate the general combining ability, specific combining ability and heterosis for yield per plant (g) and yield components, namely number of fruits per plant, individual fruit weight (g) fruit length (cm), fruit diameter (cm), locule number, and fruit thickness (cm). The experiment was conducted from March to August 2013 at Bogor Agricultural University Experiment Field, Bogor-Indonesia. Randomized Complete Block Design was used with three replications. Data from Fl generation and parents were analyzed using the Griffing Method. Significant differences among genotypes were obtained for all the traits. The variances for general combining ability (GCA) and specific combining ability (SCA) were highly significant indicating the presence of additive as well as non-additive gene effects except the fruit thickness. The tomato genotype IPB 78 is parental with the best general combining ability for yield per plant, individual fruit weight, fruit length, and fruit thickness. The tomato genotype IPB T73 x IPB T3 proved to be the best general combiner for yield and number of fruits per plant. The tomato genotype IPB T3 x IPB T1 proved to exhibit best heterosis for yield per plant and fruit thickness.

Keywords: combining ability, diallel, GCA, heterosis, SCA

Introduction

Tomato is kind of vegetable which has been cultivated worldwide. Tomato contain nutrition fact as vitamin A, C, lycopene, flavonoid and other minerals that are good for human health (Kailaku *et al*. 2007; Bhowmik *et al.* 2012; Akhtar and Hazra, 2013) Therefore, tomato may be functioned as vegetable, table fruit, drinks, raw material for cosmetic and herbs. In Indonesia, tomato becomes important horticulture commodity. Based on data from Directorate General of Horticulture (2011), in year 2011 the production of tomato in Indonesia reached 954,046 ton with the productivity of 14.2 ton/ha, but this production level still could not be able to fulfill the domestic needs, because in the same year, the total import value reached US$ 9,066,578.

The cultivation of tomato in lowland experience many obstacles, such as low productivity. The nature of its fruit set which is induced by low temperature may cause decreased productivity in tropical lowland area (Dane *et al.* 1991; Hanson *et al.* 2002). One effort in order to increase productivity as well as quality of tomato is through application of different plant breeding methods. The improvement of its characters with high economic values often face challenge when selecting parents with high combining ability. Therefore, the effective study for parent selection is highly needed. The observation to the performance of hybrid offsprings can be conducted using diallel crossing method. This progeny test can be related to the Combining Ability which are very useful in determining the parent combination for the best progeny with potentially high productivity and other selected novel characters (Baihaki, 2000; Syukur *et al.* 2012).

Some information can be obtained from diallel analysisi e.g. general combining ability (GCA) and specific combining ability (SCA) from crossing parental lines. GCA is the performance of line as combination of solely crossing with other lines, whereas SCA is the performance of a hybrid line resulted from the cross with other line (Singh and Chaudary, 1979). Combining ability is a measurement of plant genotype ability in crossing to produce superior plants. Combining ability which is obtained from a cross between two parental lines can provide information regarding cross combinations for better heredity (Sujiprihati *et al*. 2008). The analysis of diallel crossing is needed to predict the additive and dominant effects from a certain population that can be used further to predict the genetic variability and heritability (Baihaki, 2000). This analysis is often used for many kind of plant, such as tomato (Rai *et al.* 2005; Hannan *et al.* 2007a; Hannan *et al*. 2007b; Sekhar *et al.* 2010; Farzane *et al.* 2012; Saleem *et al.* 2013; Saputra *et al.* 2014), chilli (Sujiprihati *et al.* 2007), eggplant (Nalini *et al.* 2011) and corn (Iriany *et al.* 2011).

Beside combining ability, value of heterosis can also be used as one important consideration for selecting paretn genotype and novel hybrid. The information of heterosis value on certain selected genotypes can be very useful for development hybrid novel variety (Amanullah *et al.* 2011). The objective of this research was to obtain the information of GCA, SCA and heterosis value on tested tomato.

Material and methods

The research was conducted from March to August 2013, located at Plant Breeding Laboratory, Faculty of Agriculture, Bogor Agricultural University (IPB) and at Research Field Leuwikopo, IPB (250 m above sea level). The type of soil is latosol. Plant material used were consisted of 6 breeding lines, namely IPBTl, IPBT3, IPBT13, IPBT64, IPB T73 and IPB T78. The hybrid from fully diallel cross used, were 15 F_1 and 15 F_1R (R for Reciprocal) .

The research was carried out using randomized complete block design with three replications. Each experimental unit consisted of 20 plants with an area of 1m x 5m bench covered by black silver plastic mulch. The size of planting rows was 50cm x 50cm. The seedlings were tranplanted to the field after emergence of 4-5 true leaves (around 4 weeks old). Fertilizing was done every week, with solution 10 g Nitrogen: Phosphor: Pothasium (16:16: 16), 250 ml each. Pesticide was sprayed every two weeks with fungicide mancozeb 80% or propineb 2 g l^{-1}, insecticide profenovos with dose 2 ml l^{-1}. The pinching of lateral shoots was done for having optimal growth of the plants. Weeding was also done manually. Harvesting was done when tomatoes have been 75% rippened, every five days, totally eight times.

The observation was conducted on 10 sample plants from each units. The characters observed were namely yield/ plant (g per plant), fruit amount, fruit weight (g), fruit length (cm), fruit diameter (mm), and amount of locule per fruit (cm). The observation of weight, length, and diameter of fruit were measured from the same fruit two days after harvesting.

The data were analysed using Method I of Grifing (Singh and Chaudhary, 1979). The Ratio of Genetic influence (RG) was calculated based on Baker formula (1978). The estimation of heterosis value of hybrid was analysed based on the mean of both parents (mid parent heterosis) and heterobeltiosis value was analysed based on the mean of the better parent (Fehr, 1987). Data analysis was done by Microsoft Excel.

Results and discussion

The analysis of variance showed the existence of significant variation among genotypes for yield (yield per plant) and yield component (number of fruits, individual fruit weight, fruit length, fruit width, number of locule and fruit thickness). Table 1 shows mean squares from the analysis of variance for all the characters. Presence of significant differences among genotypes for all the characters, allowed combining ability analysis (Singh and Chaudhary, 1979).

The analysis of variance for combining ability showed the existence of significant variation due to both GCA and SCA for all the character, indicating that both GCA and SCA effects played important roles in controlling those traits except fruit thickness character for SCA. Highly significant variation due to both of GCA and SCA indicated the importance of additive as well as non-additive gene action in inheritance of all characters except fruit thickness. Hannan *et al.* (2007a) and Hannan *et al.* (2007b) evaluated GCA and SCA on a 10 × 10 diallel set of tomato excluding reciprocals. The result showed highly significant variation for both GCA and SCA for yield per plant, number of fruits per plant, fruit weight per plant. Gaikwad *et al.* (2009) reported highly significant GCA and SCA variances which indicated the importance of both additive and non-additive gene action in the expression of all the characters observed. However, the ratio of components of genetic variance revealed the predominant role of non-additive gene actions in controlling total yield, marketable yield, number of fruits *per* plant, average fruit weight, pericarp thickness, and number of locules. Gul (2011) indicated highly significant GCA and SCA for characters fruit length, fruit width, and fruit weight on 8×8 half diallel cross. Similarly, Farzane (2012) demonstrated highly significant variation due to GCA as well as SCA indicated the role of additive as well as non-additive types of gene action in inheritance of yield and yield component (individual fruit weight and number of locule) characters by DGU and DGK analyzed on full diallel cross 10 × 10. Saputra *et al.* (2014) also showed similar result, that GCA significantly changed the individual fruit weight, fruit size, number of fruit per plant and fruit weight *per* plant. SCA gave significant influence on the character of individual fruit weight, fruit size and fruit weight *per* plant.

The influence of reciprocals occurred in all observed characters. It indicated the influence of female parents or maternal effects. It caused the hybrid performance unequal with their reciprocal. Farzane (2012) showed the influence of reciprocals in yield and yield component (individual fruit weight, number of fruit *per* plant and number of locule).

Based on genetic ratio analysis for character yield *per* plant, number of fruit, individual fruit weight, fruit length, fruit width, number of locule, and fruit thickness are 1.63, 1.62, 1.36, 1.60, 1.10, 1.76 and 1.68, consecutively (Table 2). It indicated the importance of additive more important than non-additive types of gene action in inheritance of all characters. The result was different from Gaikwad *et al.* (2009) since the population was different. Different population will cause different gene action as well. According to Syukur *et al.* (2012), the characters which are controlled by additive genes will be easier to be selected particulary for improving the inbred line varieties.

The positive general combining ability (GCA) effect for yield *per* plant was recorded in IPBT3, IPBT13, and IPBT78, number of fruit per plant (IPBT3, and IPBT78), individual fruit weight (IPBT1, IPBT13, and IPBT78), fruit length (IPBT1, IPBT13, IPBT64 and IPBT78), fruit width (IPBT1, IPBT13, IPBT73, and IPBT78), number of locule (IPBT1 and IPBT IPBT73). The negative GCA for character fruit thickness was record in IPBT1 and IPBT73. The highest GCA effects for yield per plant, individual fruit weight, fruit length, and fruit thickness were record in IPBT78 genotype. The highest GCA effect for number of fruit was record in IPBT1 (1.35) and for locule number in IPBT3 (-0.62). The GCA effect on locule number directed towards negative since the few locule number is preferred. The negative combining ability effect indicated the genotypes or cross combiner contributed to decreasing performance in certain characters while the positive combining effect indicated the genotypes or cross combiner contributed to increasing performance in certain characters. GCA and SCA positive effects are used during genotype selection with high yield. In contrasting, GCA and SCA negative effect are used during genotype selection towards pathogen resistance (Yustiana, 2013).

Table 4 indicated the highest SCA estimated for yield *per* plant in combiner IPBT73 × IPBT13 (482.39) followed by IPBT1 × IPBT73, IPBT3 × IPBT64, IPBT13 × IPBT73 and IPBT64 × IPBT78. The highest SCA estimated for number of fruit was record in IPBT73 × IPBT3 (48.37) and the effect was high in IPBT13 × IPBT3, IPBT13 × IPBT73. The highest SCA estimated for individual fruit weight was record in IPBT64 × IPBT78 (10.35) with the high combiner IPBT78 × IPBT13. Highest estimated SCA for fruit length was recorded in IPBT1 × IPBT78 (5.85) and such effects were higher in IPBT1 × IPBT64 and IPBT73 × IPBT78. The highest estimated SCA for fruit width was record in IPBT78 × IPBT13 (4.25) followed other combiners IPBT1 × IPBT13 and IPBT64 × IPBT13. The highest SCA estimate for number of locule was record in IPBT73 × IPBT3 (-1.88). The highest SCA estimate for fruit thickness was record in IPBT73 × IPBT78 (0.47)

The estimated GCA and heterosis effect was influence by dominant gene action types. Therefore, GCA and heterosis effect are positively associated (Yustiana, 2013). Mid-parent heterosis (MPH) and best-parent heterosis was highest for yield *per* plant (58.8%; 42.2%) and fruit thickness (20.8%; 8.1%) in IPBT3 × IPBT1, number of fruit (82.5%; 50.4%) in IPBT73 × IPBT13, individual fruit weight (37.2%; 31.2%) and fruit width (15.4%; 9.4%) in IPBT78 x IPBT13, fruit length (9.4%; 5.9%) in IPBT1 × IPBT13, and MPH for number of locule (72.8%) in IPBT73 × IPBT64 and it BPH (37.7%) in IPBT78 × IPBT3.

Heterosis value ≥ 20% on yield component of self-pollinating plants as rice gives opportunities to hybrid varieties breeding programs. Based on MPH and BPH value, the results of this research showed that there is a potential to develop hybrids with more yield per plant, number of fruit, individual fruit weight, and number of locule. Hanan *et al.* (2007b) reported similar results that heterosis occur for yield per plant (19.3-34.9%), number of fruit (10.0-20.0%), fruit weight (9.6-48.7%), fruit length (14.8-32.7%) and maximum heterosis for fruit width 10.6%. Ahmad *et al.* (2011) indicated that BPH for yield per plant reach 32.09%. Farzane (2012) reported high MPH for number of fruit (25.03%) and yield per plant (36.82%).

Conclusions

Both additive and dominant gene action types play an important role in controlling yield and yield component in tomato at lowland, but additive gene action was more prominent to controlling yield *per* plant, number of fruit, individual fruit weight, fruit length, fruit width, number of locule and fruit thickness. The influence of reciprocals occurred in all the observed characters. Tomato genotype IPBT78 proved to be the best general combiner for yield and yield components. The best cross combinations were IPBT73 × IPBT13 for yield per plant and number of fruit per plant.

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Table 1. Analysis of variance for yield and yield component in tomato

Source	Df	Mean squares						
		Yield plant^{-1}	Number of fruits	Individual fruit weight	Fruit length	Fruit width	Number of locules	Fruit thickness
Replication	2	541318.65^{ns}	300.45^{ns}	541318.65^{ns}	11.36^{ns}	17.12^{ns}	0.53^{ns}	1.27^{ns}
Genotype	35	401656.43**	2349.11**	401656.43**	141.69**	52.93**	8.41**	0.81**
Error	70	123385.76	238.57	123385.76	11.56	14.28	0.52	0.29

* Significant at P=0.05, ** Significant at P=0.01, ^{ns} non significant

Table 2. Mean squares from a combining ability analysis, additive variance, dominant variance and genetic ratio for yield and yield components in a diallel cross of Tomato.

Source	Df	Yield plant^{-1}	Number of fruits	Individual fruit weight	Fruit length	Fruit width	Number of locules	Fruit thickness
GCA	5	333012.27**	1492.08**	197.90**	138.31**	18.70**	10.73**	0.83**
SCA	15	75424.91**	345.61**	92.55**	34.07**	15.45**	1.48**	0.16^{ns}
Reciprocal	15	123385.76**	984.11**	132.03**	30.03**	19.50**	1.49**	0.30*
Error	70	41128.59	79.52	25.65	3.85	4.76	0.17	0.10
V add		43115.62	192.51	17.92	17.54	0.60	1.55	0.11
V dom		19913.99	154.50	38.84	17.54	6.20	0.76	0.04
RG		1.63	1.62	1.36	1.60	1.10	1.76	1.68
CV (%)		29.76	24.64	22.59	9.12	9.16	17.65	12.76

* Significant at P=0.05, ** Significant at P=0.01, ^{ns} Non Significant

Table 3. General combining ability (GCA) effects of parents for yield and yield component

Genotype	Character						
	Yield plant^{-1}	Number of fruits	Individual fruit weight	Fruit length	Fruit width	Number of locules	Fruit thickness
IPB T1	-116.15	-11.96	4.64	2.46	1.35	0.41	-0.08
IPB T3	58.09	13.82	-4.68	-0.63	-2.32	-0.62	0.10
IPB T13	49.08	-0.94	1.62	0.87	0.75	-0.08	0.18
IPB T64	-102.42	-10.17	-0.21	2.49	-1.04	-0.45	0.17
IPB T73	-176.71	-2.93	-1.19	-2.34	0.89	1.29	-0.25
IPB T78	142.52	1.58	5.17	4.61	0.57	-0.37	0.27

Table 4. Specific combining ability (SCA) effects of parents for yield and yield component

Genotype	Character						
	Yield plant-1	Number of fruits	Individual fruit weight	Fruit length	Fruit width	Number of locules	Fruit thickness
IPBT1 x IPBT3	-250.03	19.71	-15.07	-5.79	-6.09	-0.99	-0.24
IPBT1 x IPBT13	40.04	-9.23	7.32	1.98	3.76	0.14	0.24
IPBT1 x IPBT64	57.30	-0.48	6.33	4.72	2.11	-0.67	0.41
IPBT1 x IPBT73	297.77	8.12	0.69	-4.47	2.13	1.06	-0.13
IPBT1 x IPBT78	-15.88	-5.04	3.41	5.85	-0.44	-0.60	0.23
IPBT3 x IPBT1	-186.21	-25.57	1.83	-0.09	0.83	0.57	-0.52
IPBT3 x IPBT13	-96.11	-10.73	6.82	2.06	3.06	0.78	-0.12
IPBT3 x IPBT64	157.93	-2.61	-0.99	1.26	-1.39	0.07	0.00
IPBT3 x IPBT73	-167.47	-4.23	4.85	1.41	1.42	-0.49	0.02
IPBT3 x IPBT78	132.92	2.42	0.39	0.66	0.64	0.29	-0.14
IPBT13 x IPBT1	-182.75	-9.35	3.42	2.44	1.13	0.53	-0.26
IPBT13 x IPBT3	101.76	22.05	-9.17	-3.01	-3.57	-0.55	-0.32
IPBT13 x IPBT64	-171.50	-4.78	-2.24	-0.19	-1.21	-0.28	0.27
IPBT13 x IPBT73	183.53	27.13	-4.32	-0.20	-2.62	-0.64	-0.08
IPBT13 x IPBT78	-14.76	3.53	-2.83	-2.81	-0.23	0.50	-0.20
IPBT64 x IPBT1	63.38	0.48	1.58	-2.28	2.35	0.89	-0.14
IPBT64 x IPBT3	-27.05	14.26	-7.52	-2.99	-2.89	-0.57	-0.17
IPBT64 x IPBT13	-91.94	-8.87	7.97	2.34	3.45	0.62	0.25
IPBT64 x IPBT73	18.59	5.44	-5.45	-3.98	-0.69	0.28	-0.21
IPBT64 x IPBT78	153.59	-0.29	10.35	3.09	3.37	0.49	-0.02
IPBT73 x IPBT1	18.66	-7.72	7.56	3.65	1.26	-0.89	0.19
IPBT73 x IPBT3	482.39	48.37	-10.53	-1.42	-4.29	-1.88	0.12
IPBT73 x IPBT13	-61.26	-29.72	1.34	0.26	-0.38	0.37	-0.12
IPBT73 x IPBT64	-495.26	-27.67	-7.35	-0.06	-4.78	-1.38	-0.11
IPBT73 x IPBT78	-410.99	-24.59	-1.59	4.33	-2.83	-1.85	0.47
IPBT78 x IPBT1	-118.82	-8.39	2.73	-3.87	2.12	1.00	-0.52
IPBT78 x IPBT3	40.09	18.58	-11.97	-5.85	-3.17	-0.20	-0.13
IPBT78 x IPBT13	-277.20	-36.39	10.26	3.87	4.25	0.38	0.06
IPBT78 x IPBT64	-198.93	-5.95	-9.29	0.45	-4.47	-0.76	-0.11
IPBT78 x IPBT73	-488.79	-6.93	-14.22	-10.53	-3.20	0.77	-0.75

Table 5. Mid-parent heterosis (MPH) and best-parent heterosis (BPH)

Genotype	Yield plant^{-1}		Number of fruits		Individual fruit weight		Fruit length		Fruit width		Number of locules		Fruit thickness	
	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH
IPBT1 x IPBT3	-28.6	-36.0	7.9	-32.9	-23.4	-43.0	-10.7	-19.1	-7.5	-17.3	-17.4	-43.0	-14.0	-23.0
IPBT1 x IPBT13	-2.5	-24.5	-36.0	-56.7	14.3	13.2	9.4	5.9	8.1	5.0	-1.7	-20.7	1.9	-10.9
IPBT1 x IPBT64	24.2	12.6	16.2	-14.1	10.6	6.4	-0.4	-9.4	10.8	10.5	1.0	-28.5	9.5	-5.8
IPBT1 x IPBT73	19.0	3.4	8.2	-25.6	23.0	6.6	2.0	-15.0	8.0	5.7	-9.3	-21.6	7.7	4.6
IPBT1 x IPBT78	1.5	-17.9	-18.4	-41.1	15.3	11.2	-2.0	-14.5	7.7	5.0	4.0	-27.9	-6.5	-20.4
IPBT3 x IPBT1	58.8	42.2	37.8	-14.3	1.1	-24.7	-4.5	-13.4	3.1	-7.9	-25.5	-48.6	20.8	8.1
IPBT3 x IPBT13	12.8	-4.5	38.3	16.5	-12.0	-34.1	-5.9	-12.0	-2.4	-14.9	7.9	-12.7	-14.1	-16.3
IPBT3 x IPBT64	26.8	25.2	6.9	-19.4	-24.6	-45.2	-11.4	-26.2	-8.6	-18.1	3.8	-0.7	-7.4	-11.5
IPBT3 x IPBT73	20.9	16.8	60.2	32.0	-8.0	-23.3	3.9	-5.5	-4.8	-16.5	-46.5	-65.9	0.6	-12.2
IPBT3 x IPBT78	31.0	16.6	32.9	2.9	-22.1	-43.3	-19.5	-35.3	-0.3	-8.8	27.0	26.1	-12.1	-16.9
IPBT13 x IPBT1	5.7	-18.1	32.7	-10.1	6.1	5.1	0.6	-2.6	3.9	0.9	-10.7	-27.9	11.0	-2.9
IPBT13 x IPBT3	30.5	10.5	16.4	-1.9	-14.5	-35.9	-6.7	-12.8	-2.9	-15.4	-9.0	-26.4	-6.5	-9.0
IPBT13 x IPBT64	-14.2	-28.1	12.5	-2.0	-8.9	-13.1	-8.3	-19.0	-1.1	-4.2	14.9	-3.6	5.0	3.1
IPBT13 x IPBT73	-2.0	-14.5	24.3	21.0	-23.5	-33.2	-4.9	-18.6	-12.9	-13.5	-13.5	-37.4	-9.8	-23.1
IPBT13 x IPBT78	-11.1	-16.0	-2.4	-12.1	3.3	-1.3	-10.9	-24.4	6.3	0.8	31.8	7.3	-11.2	-13.9
IPBT64 x IPBT1	47.7	33.9	55.7	15.1	-11.3	-14.6	-5.4	-13.9	-4.7	-4.9	-14.8	-39.7	10.9	-4.5
IPBT64 x IPBT3	23.0	21.4	19.1	-10.2	-25.0	-45.5	-14.3	-28.6	-4.2	-14.1	-3.2	-7.4	-2.9	-7.2
IPBT64 x IPBT13	-30.8	-42.0	-2.8	-15.3	-30.3	-33.5	-15.8	-25.6	-11.0	-13.8	7.3	-10.0	-12.2	-13.8
IPBT64 x IPBT73	-60.3	-62.1	-49.0	-54.5	-42.6	-51.9	-19.9	-38.0	-15.6	-17.6	-19.5	-47.6	-11.8	-25.9
IPBT64 x IPBT78	6.6	-6.2	-15.0	-18.1	-7.0	-7.2	-8.4	-12.5	-2.3	-4.5	15.8	11.5	-9.8	-10.9
IPBT73 x IPBT1	-65.6	-70.1	-9.3	-37.6	18.4	2.6	0.9	-15.9	5.0	2.8	-7.3	-19.9	7.6	4.5
IPBT73 x IPBT3	30.3	25.8	82.5	50.4	-2.4	-18.6	1.2	-8.0	2.1	-10.5	-15.9	-46.3	-1.1	-13.7
IPBT73 x IPBT13	8.5	-5.4	21.7	18.4	-1.6	-14.0	-5.4	-19.0	3.1	2.4	19.1	-13.8	-4.2	-18.3
IPBT73 x IPBT64	-25.1	-28.5	-19.7	-28.4	-7.7	-22.6	-19.9	-38.0	5.4	2.9	72.8	12.6	-23.2	-35.5
IPBT73 x IPBT78	-83.0	-84.4	1.7	-6.2	-40.3	-49.9	-24.8	-43.7	-14.0	-17.8	-20.5	-49.1	-13.6	-28.2
IPBT78 x IPBT1	36.7	10.6	8.5	-21.7	9.5	5.6	-0.9	-13.5	4.2	1.6	-20.2	-44.7	3.4	-11.9
IPBT78 x IPBT3	53.1	36.2	81.5	40.5	-22.0	-43.2	-23.8	-38.8	0.0	-8.6	38.7	37.7	-11.3	-16.2
IPBT78 x IPBT13	16.6	10.1	15.6	4.0	37.2	31.2	1.0	-14.2	15.4	9.4	44.1	17.3	-3.8	-6.8
IPBT78 x IPBT64	1.5	-10.7	1.6	-2.0	8.0	7.8	0.2	-4.4	3.7	1.4	10.1	6.0	2.6	1.3
IPBT78 x IPBT73	35.8	24.7	-2.4	-9.9	-5.9	-20.9	-14.4	-35.9	-2.3	-6.7	-22.5	-50.4	0.4	-16.5

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