Performance of Seedling and Early Field Growth and Yield of *Jatropha curcas* L. Hybrid Progenies in North Lombok Dry Land, Indonesia

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Abstract

Development of Jatropha as a source of biodiesel to dry land, a wide area in Indonesia, has been an urgent situation due to limitation of fossil fuel. The use of superior varieties is an imperative effort, however, their number is still limited. Some local genotypes which were originally from West Nusa Tenggara, namely IP-3A, IP-1A, West Lombok Genotype, Bima Genotype, IP-2NTB and others, have specific superior character such as drought stress tolerant and high yield. The result of completely dialell hybridization among them showed that some hybrids namely 2NTBx3A, LBx2NTB, 3Ax2NTB, 3Ax1A-a, LBx3A, 3Ax1A-b, and BMx3A had superior characters in term of seedling growth, vegetative growth and yield in the first year of production cycle, compared to the other hybrids and their parentals. The growth and the general performance were getting better in the F2 generation in the second year of production cycle. The hybrid of 2NTBx3A and 3Ax1A showed the highest yield potency (98.7 g and 101.1 g, respectively), compared with the other hybrid populations.

Keywords: biodiesel, dry land, hybrids, growth, yield

Introduction

Developing of high yield varieties of Jatropha needs plant material having superior charakteristics genetically, such as high number of seed, quick harvesting, and widely adaptive to unfavourable environments (Hasnam and Mahmud, 2006). Leon *et al.* (2003) stated that oil yield of jatropha per plant was determined by number of seed per stalk or plant, weight of seed, and oil seed content that were genetic characteristics, however, they can still be modified by environmental factors.

Callaham (1999) suggested that some additional characters that should be given an attention to describe a provenan to breed jatropha were germination rate and further growth, time of budding, time of flowering, length of reproduction period, resistancy of environmental stress including plant nutritions, and pest resistency. In order to get the plant population with seed production ranging from 4 to 7 ton/ha, jatropha breeding program must produce the plants producing 850-1000 capsul/plant/year, after the plants reach mature (4-5 years old) (Santoso, 2009; Hasnam *et.al*., 2007).

Breeding program of jatropha, especially West Nusa Tenggara genotypes, carried out is to improve plant population composition using plant individual having high seed yield potency. Due to cross pollination characteristic, improving jatropha population genetically based on their population improvement should be using mass selection and followed by bulk of superior plants selected. Hallauer (1981) stated that, mass selection is an efective method to improve plant population resulted from introgressi of exotic plant germ plasm or undomesticated plants.

The plant genetic improvement program through mass selection of some West Nusa Tenggara genotypes of jatropha resulted *Improved Population*-1 and *Improved Population*-2 (IP-1 NTB and IP-2 NTB) having higher yield potency compared to their parentals (Santoso *et.al.*, 2012).

Using some jatropha genotypes of West Nusa Tenggara, Asembagus and Lampung, Hasnam (2007) resulted some improved populations, such as IP-1A, IP-3A, dan IP-3P. And then, the improved populations can be used as parentals to create a new superior hybrid. This paper explains the early performance of some F1 and F2 hybrids resulted from crossing of some those superior populations.

Materials and Methods

The research was a series experiment consisted of two experiments. In the first experiment it used a grid system. Each parental and its hybrid were planted in a grid (small plot) with 50 plant population. The hybrids were resulted from completely dialel hybridization from four parentals. The parentals were improved population of NTB2 (IP-2NTB), genotype of West Lombok (LB), improved population of Asembagus1 (IP-1A) improved population of Asembagus3 (IP-3A), genotype of Lampung (L), and genotype of Bima (BM). Hybrid evaluation consisted of two steps. The first evaluation was carried out in seedling period when the seedlings were grown in The Faculty of Agriculture, The University of Mataram, Mataram, and the second was early growth after the seedlings were transplanted into field production in Amor-amor area, Gumantar Village, Kayangan District, North Lombok, West Nusa Tenggara, Indonesia.

Seeds were planted in the polybag containing soil compos mixture (1:1 – v/v), and placed in shadow area with light intensity of 35–40%. Each polybag was sown one seed. Seedlings were maintained as stantard maintenance of jatropha seedling. Field experiment was arranged using grid system, and the populations were the seedlings resulted from the seedling process of each F1 hybrid before. Planting hole were made with 1.5 x 1.5 in space, and filled with 1 kg of manure, 5 g of Furadan, 135 g of Urea, and 80 g of Fonska fertilizer. Further Fonska about 160 g were applied when the plants were two months old. The seedling were then planted and maintained following planting and maintaining standard of jatropha. The capsules (fruits) were harvested when their colour were yellowing. The seeds, and then, were dried using sun drying for 2 – 3 days until the seed moisture content was about 7%. The parameter observed during seedling period were number of leaves, seedling height, collar diameter, root and shoot dry weight, and plant height, collar diameter, width of canopy, number of primary and productive branches at the end of the experiment.

The second experiment was to plant the hybrids resulted from the first experiment carried out in the second year. The hybrid seeds were planted using grid system next to the first experiment. Each grid consisted of 25 plants. Seedling, planting and maintaining followed standard jatropha cultivation. The fruits were harvested when their colour were yellowing. The seeds, and then, were dried using sun drying for 2 – 3 days until the seed moisture content was about 7%. The parameters observed were similar to the parameter observed in the first experiment.

Result and Discussion

Analysis of variance of the seedling, vegetative and reproductive (yield) characters revealed that there was a significant variation among all F1 hybrids and their parents studied in all characters at $P \leq 0.05$. Significant variation was observed in seedling traits (Table 1), and during vegetative growth and reproductive characters of progeny of 15 F1 hybrids and their parental (Table 3 and Table 4).

During seedling period, F1 hybrids of 2NTBx3A, LBx2NTB, 3Ax2NTB, 3Ax1A, LBx3A, 3Ax1A-b, and BMx3A showed better growth and performance, especially in the seedling dry weight (shoot and root) compared to their parentals and other hybrids (Table 1). The result of this study is not in line with finding Tar *et al*. (2011) stating that the hybrid seedlings (F1) did not showed better and bad growth and perfomance compared to their parents. Parwata *et al.* (2014) also found that there was no significant difference among some jatropha accessions during vegetative growth.

Table 1: Mean of two month old seedling growth characteristics of F-1 jatropha hybrids and their parentals

Code	Genotype	Leave number	Seedling height (cm)	Collar diameter (cm)	Root dry weight (g)	Shoot dry weight (g)
IP-2NTB	NTB	9.66±0.84	23.66±1.77	13.91±2.49	1.99±0.92	8.51±0.86
LB	Lombok Barat	6.57±1.02	18.35±3.18	14.45±2.29	1.75±1.01	7.33±1.13
IP-3A	Asembagus-NTB	8.33±1.40	23.02±2.82	11.51±1.35	1.91±1.03	7.98±0.94
IP-1A	Asembagus-NTB	7.27±1.44	20.89±2.79	13.16±2.35	1.87±1.88	7.94±1.07
L	Lampung	6.34±1.11	18.19±1.73	12.02±1.82	1.58±1.36	7.12±2.03
BM	Bima	6.69±1.33	18.35±2.05	13.22±2.01	1.93±0.88	8.44±0.91
2NTBxLB	Hybrid	9.52±0.95	23.43±1.79	14.44±1.43	1.72±1.03	7.02±1.09
2NTBx3A	Hybrid	8.43±0.65	24.87±0.87	16.21±0.72	**2.47±1.66**	**7.44±1.08**
2NTBx1A	Hybrid	7.95±0.83	23.92±1.22	15.39±0.68	1.77±1.68	7.74±1.02
3AxLB	Hybrid	9.22±0.58	26.02±1.31	15.07±0.93	1.71±1.01	7.13±1.18
LBx2NTB	Hybrid	8.19±0.84	23.66±1.17	13.87±1.02	**2.42±0.97**	**8.22±0.89**
3Ax2NTB	Hybrid	7.25±0.96	26.38±1.60	13.93±0.68	**2.31±1.74**	**7.74±1.37**
3Ax1A	Hybrid	6.67±1.15	20.01±1.50	16.20±0.70	**2.12±1.84**	**7.85±1.11**
1AxLB	Hybrid	7.56±1.67	21.49±3.44	14.47±0.89	1.91±1.85	7.74±1.09
1Ax3A	Hybrid	10.0±2.14	25.05±1.34	11.80±2.40	1.93±1.13	6.35±0.98
LBx3A	Hybrid	8.33±3.21	18.37±2.83	17.25±1.48	**1.98±1.03**	**7.91±1.19**
3Ax1A-b	Hybrid	8.06±1.24	22.53±3.03	11.93±1.23	**2.75±1.08**	**7.24±1.28**
1Ax2NTB	Hybrid	6.76±1.51	19.78±1.52	16.25±0.76	1.79±1.33	7.22±1.06
LBxL	Hybrid	9.29±1.46	23.09±2.52	14.56±1.42	1.55±1.66	6.52±2.13
BMx3A	Hybrid	6.64±1.53	18.69±2.07	13.41±2.22	**2.49±1.07**	**8.14±1.67**
Lx1A	Hybrid	8.38±1.62	22.47±2.63	14.22±1.37	1.51±1.65	7.41±2.51

Explanation : ± symbol = standard error

The better growth and performance during seedling period also affected on the vegetative growth after replanting at the production field (Table 2). There was a significant difference during vegetative growth among hybrids and their parents in term of plant height, collar diameter, and width canopy, number of primary and productive branch. F1 hybrids of 2NTBx3A, LBx2NTB, 3Ax2NTB, 3Ax1A, LBx3A, 3Ax1A-b, and BMx3A also showed the better growth and performance on vegetative growth after field planting.

The better growth and performance during seedling period also affected on the growth and yield component of the first year production cycle (Table 4). There were 7 F1 hybrids had the best growth and seed yield per plant compared to other hybrids and their parents. There were F1 hybrids of 2NTBx3A, LBx2NTB, 3Ax2NTB, 3Ax1A, LBx3A, 3Ax1A-b, and BMx3A. This indicates that there was heterosis on the vegetative and reproductive characteristics showed by some hybrids. As the purpose of plant crossing is to combine a number of characteristics possessed by the parental genotype so that it will give a number of new genotypes results with the characteristics inherited by their parentals.

Table 2: Vegetative characters of F-1 jatropha hybrids and their parentals at the first production cycle

Code	Genotype	Plant height (cm)	Collar diameter (cm)	Canopy Width (cm)	Primary branch	Productive branch
IP-2NTB	NTB	158.1 ± 1.8	8.4 ± 0.9	83.3 ± 2.9	4.5 ± 1.7	6.2 ± 3.1
LB	Lombok Barat	156.4 ± 2.1	8.6 ± 1.1	81.7 ± 3.1	4.2 ± 1.9	6.5 ± 3.5
IP-3A	Asembagus-NTB	157.1 ± 1.2	8.8 ± 0.7	82.8 ± 2.8	4.3 ± 2.3	6.2 ± 2.6
IP-1A	Asembagus-NTB	153.8 ± 1.6	8.5 ± 0.9	85.5 ± 3.4	4.5 ± 2.6	6.6 ± 2.9
L	Lampung	139.5 ± 3.2	7.6 ± 1.3	75.7 ± 3.7	3.4 ± 2.1	5.6 ± 3.3
BM	Bima	142.7 ± 2.3	8.2 ± 1.2	80.4 ± 2.5	4.1 ± 2.4	5.8 ± 3.6
2NTBxLB	Hybrid	147.7 ± 3.9	7.7 ± 1.4	77.8 ± 3.6	3.9 ± 2.2	5.6 ± 2.8
2NTBx3A	Hybrid	**160.8 ± 4.5**	**8.9 ± 1.9**	**90.8 ± 4.9**	**5.5 ± 3.4**	**7.2 ± 3.3**
2NTBx1A	Hybrid	158.8 ± 3.6	8.2 ± 1.2	79.8 ± 3.7	4.1 ± 2.8	5.5 ± 2.8
3AxLB	Hybrid	151.2 ± 3.3	7.7 ± 1.2	82.1 ± 3.5	4.0 ± 2.6	5.2 ± 3.1
LBx2NTB	Hybrid	**161.6 ± 4.9**	**9.1 ± 1.4**	**92.3 ± 4.4**	**5.9 ± 3.7**	**7.9 ± 3.8**
3Ax2NTB	Hybrid	**165.9 ± 4.3**	**8.9 ± 1.7**	**95.2 ± 4.5**	**5.1 ± 2.9**	**7.6 ± 3.3**
3Ax1A	Hybrid	**162.2 ± 5.1**	**9.2 ± 1.2**	**98.1 ± 4.1**	**5.2 ± 2.3**	**7.9 ± 3.1**
1AxLB	Hybrid	152.8 ± 3.8	7.6 ± 1.4	78.8 ± 2.6	3.5 ± 2.8	5.1 ± 2.2
1Ax3A	Hybrid	155.5 ± 2.6	8.2 ± 1.1	82.2 ± 1.8	4.1 ± 3.2	6.1 ± 2.9
LBx3A	Hybrid	**164.4 ± 5.5**	**9.3 ± 1.5**	**96.8 ± 4.3**	**5.1 ± 2.8**	**7.8 ± 3.6**
3Ax1A-b	Hybrid	**165.7 ± 6.2**	**9.1 ± 1.2**	**90.9 ± 4.7**	**5.9 ± 3.6**	**7.5 ± 3.7**
1Ax2NTB	Hybrid	156.4 ± 2.8	8.3 ± 1,0	77.4 ± 3.5	4.3 ± 3.0	6.2 ± 3.1
LBxL	Hybrid	146.6 ± 3.2	7.6 ± 0.9	72.6 ± 3.1	3.6 ± 2.9	4.9 ± 2.9
BMx3A	Hybrid	**162.4 ± 4.8**	**8.9 ± 1.6**	**92.7 ± 5.1**	**5.0 ± 3.2**	**7.8 ± 3.7**
Lx1A	Hybrid	146.2 ± 2.5	7.3 ± 0.8	81.1 ± 3.0	4.2 ± 3.1	5.1 ± 2.6

Explanation: ± symbol = standard error

Table 3: Reproductive characters of F-1 jatropha hybrids and their parentals at the first production cycle

Code	Genotype	Inflorescence time*)	Fruit number per plant	Harvesting time*)	Seed dry weight (g)	Seed dry weight (g plant^{-1})
IP-2NTB	NTB	119.9 ± 4.2	37.2 ± 2.9	174.7 ± 3.8	0.68 ± 0.05	75.8 ± 6.2
LB	Lombok Barat	122.6 ± 5.5	36.5 ± 3.1	178.2 ± 4.4	0.68 ± 0.08	75.5 ± 6.7
IP-3A	Asembagus-NTB	117.4 ± 4.1	37.4 ± 2.7	171.3 ± 3.3	0.67 ± 0.03	74.7 ± 5.5
IP-1A	Asembagus-NTB	120.8 ± 4.8	39.4 ± 3.1	173.2 ± 3.7	0.66 ± 0.05	78.1 ± 5.9
L	Lampung	159.3 ± 5.2	29.6 ± 3.6	217.6 ± 4.9	0.61 ± 0.09	56.7 ± 6.9
BM	Bima	132.9 ± 5.3	33.8 ± 3.8	188.7 ± 5.5	0.67 ± 0.10	69.2 ± 6.5
2NTBxLB	Hybrid	121.2 ± 4.7	33.6 ± 2.5	175.6 ± 3.7	0.65 ± 0.09	65.5 ± 8.1
2NTBx3A	Hybrid	**115.5 ± 6.6**	**41.8 ± 5.1**	**170.1 ± 6.2**	**0.68 ± 0.04**	**85.7 ± 5.7**
2NTBx1A	Hybrid	123.2 ± 4.4	33.4 ± 2.7	185.3 ± 5.6	0.65 ± 0.04	65.3 ± 7.7
3AxLB	Hybrid	126.3 ± 4.0	31.2 ± 2.9	181.6 ± 5.8	0.62 ± 0.03	58.3 ± 6.5
LBx2NTB	Hybrid	**116.6 ± 6.4**	**43.6 ± 4.9**	**167.8 ± 6.0**	**0.67 ± 0.03**	**87.7 ± 5.9**
3Ax2NTB	Hybrid	**115.2 ± 6.2**	**45.9 ± 4.6**	**166.2 ± 5.7**	**0.65 ± 0.05**	**89.5 ± 5.6**
3Ax1A	Hybrid	**116.3 ± 6.1**	**47.4 ± 4.4**	**162.9 ± 5.6**	**0.68 ± 0.03**	**96.7 ± 6.5**
1AxLB	Hybrid	126.2 ± 4.3	30.9 ± 2.6	173.3 ± 3.4	0.62 ± 0.05	57.7 ± 5.5
1Ax3A	Hybrid	119.8 ± 4.9	35.5 ± 3.0	170.8 ± 2.8	0.64 ± 0.04	68.7 ± 5.8
LBx3A	Hybrid	**117.1 ± 5.6**	**46.9 ± 4.6**	**162.6 ± 5.1**	**0.65 ± 0.06**	**91.9 ± 6.4**
3Ax1A-b	Hybrid	**114.8 ± 6.8**	**46.6 ± 4.5**	**165.5 ± 5.4**	**0.66 ± 0.03**	**92.8 ± 6.1**
1Ax2NTB	Hybrid	128.7 ± 3.8	37.1 ± 2.5	169.8 ± 2.4	0.62 ± 0.05	69.1 ± 6.3
LBxL	Hybrid	141.2 ± 3.1	30.1 ± 2.3	171.4 ± 3.3	0.65 ± 0.05	58.9 ± 6.1
BMx3A	Hybrid	**116.6 ± 6.5**	**44.8 ± 4.7**	**164.7 ± 5.2**	**0.67 ± 0.04**	**90.4 ± 6.2**
Lx1A	Hybrid	144.9 ± 5.8	33.4 ± 2.6	174.3 ± 3.8	0.64 ± 0.05	64.8 ± 7.7

Explanation: *) = day after transplanting; ± symbol = standard error

In this study, it was also found that there was high variability level among F1 hybrids. It means that this study could create a superior plant variety. This finding was in line with Hasnam (2011) that crossing among plus tree with high genotypic and phenotypic diversities will result in better F1 hybrids compared to their parentals. From some populations resulted from the hybridization at the first experiment, the seeds were sown to be used in the second experiment.

The populations selected (F2) showed better growth and performance in term of leaf number, seedling height, colar diameter, root and shoot dry weight (Table 4), compared to their F1 population (Table 1). There was no significant variation of the seedling vegetative growth among them.

Table 4: Growth characters of F2 populations at two months old

Code	Genotype (population)	Leave number	Seedling height (cm)	Collar diameter (cm)	Root dry weight (g)	Shoot dry weight (g)
2NTBx3A	Hybrid (25)	9.41±0.69	25.77±0.81	1.61±0.33	2.73±1.01	7.84±1.01
LBx2NTB	Hybrid (25)	9.92±0.44	24.24±1.72	1.47±0.98	2.60±0.88	8.33±0.82
3Ax2NTB	Hybrid (25)	8.51±0.67	27.44±1.22	1.33±0.87	2.44±1.44	7.80±1.02
3Ax1A-a	Hybrid (25)	7.76±1.51	21.22±1.45	1.60±0.54	2.31±1.04	8.15±1.09
LBx3A	Hybrid (25)	8.41±3.16	19.32±2.66	1.87±1.01	2.24±1.12	8.19±0.91
3Ax1A-b	Hybrid (25)	7.23±1.44	22.51±3.15	1.21±1.03	2.81±1.17	7.77±1.55
BMx3A	Hybrid (25)	7.61±1.32	19.65±2.16	1.31±1.75	2.65±1.14	8.52±1.44

Explanation : ± symbol = standard error

In the next two Tables (Table 5 and 6), it showed that the vegetative growth and reproductive characters of F2 hybrid populations after 6 months transplanted into field production. As the seedling period, the F2 hybrid populations was getting better vegetative growth and reproductive characters compared with their F1 population, in term of plant height, colar diameter, canopy width, the number of primary and productive branches, flowering time, fruit number, harvesting time and seed weight. The hybrid of 2NTBx3A and 3Ax1A showed the highest yield potency (98.7 g and 101.1 g, respectively), compared with the other hybrid populations. This superior characters might be caused by their parents, both female and male, had been improved their genetic characteristics through mass selection. Their parents (LB and SB), reported by Santoso *et.al*. (2016) were, as two superior genotypes from the existing genotype NTB provenances, showed a significant yearly yield increase during 5 years of cultivation period. Yi *et. al.* (2014) stated, that genotype of improved population was genotype that has been improved their yield and decreased their variability. Hasnam (2006) added that improved population can be used as a germplasm in breeding jatropha. Both hybrids had higher yield potency in term of fruit number per plant and longer time to fill the fruit (longer harvesting time) so much food reserve could be stored in the fruit/seed.

In this experiment, it was also found that both hybrids had higher productive branch number and inflorescence. The higher the productive branch and inflorescence number, the higher the fruit/seed number would be. This finding was in line with Tar *et. al.* (2011) state, that high yield potency of jatropha was also determined by number of productive branch and inflorescence.

Table 5: Vegetative growth of the F-2 hybrid at the first year of production cycle (6 months after transplanting)

Code	Genotype (population)	Plant height (cm)	Colar diameter (cm)	Canopy width (cm)	Number of primary branch	Number of productive branch
2NTBx3A	Hybrid (25)	161.6 ± 4.6	8.9 ± 1.9	92.8 ± 3.9	5.6 ± 3.1	7.8 ± 2.2
LBx2NTB	Hybrid (25)	160.8 ± 4.7	9.1 ± 1.1	94.3 ± 3.4	5.8 ± 3.8	7.5 ± 3.5
3Ax2NTB	Hybrid (25)	162.4 ± 4.8	9.3 ± 1.5	92.2 ± 3.7	5.5 ± 2.7	6.9 ± 3.9
3Ax1A-a	Hybrid (25)	164.4 ± 5.8	9.2 ± 1.2	96.1 ± 3.5	5.6 ± 2.6	7.7 ± 3.4
LBx3A	Hybrid (25)	162.2 ± 5.8	8.9 ± 1.3	99.8 ± 3.2	5.4 ± 2.4	7.6 ± 2.9
3Ax1A-b	Hybrid (25)	165.7 ± 6.7	9.1 ± 1.2	96.9 ± 4.1	5.8 ± 3.4	6.8 ± 3.9
BMx3A	Hybrid (25)	165.9 ± 4.9	8.9 ± 1.6	94.7 ± 4.2	5.4 ± 3.4	7.4 ± 3.5

Explanation: *) = day after transplanting; ± symbol = standard error

Table 6: Reproductive components of the F-2 hybrid at the first year of production cycle (6 months after transplanting)

Code	Genotype (population)	Flowering time*)	Fruit number per plant	Harvesting time*)	Seed dry weight (g)	Seed dry weight per plant(g)
2NTBx3A	Hybrid (25)	126.5 ± 5.3	49.6 ± 5.2	172.2 ± 5.2	0.75 ± 0.05	98.7 ± 3.5*
LBx2NTB	Hybrid (25)	120.1 ± 5.1	44.9 ± 5.4	169.7 ± 5.8	0.69 ± 0.04	90.2 ± 2.5
3Ax2NTB	Hybrid (25)	115.7 ± 5.6	49.1 ± 5.9	165.2 ± 4.8	0.77 ± 0.05	93.5 ± 4.9
3Ax1A-a	Hybrid (25)	114.6 ± 4.9	51.7 ± 6.2	160.2 ± 4.5	0.68 ± 0.09	101.1 ± 2.3*
LBx3A	Hybrid (25)	113.6 ± 5.2	51.2 ± 4.8	160.2 ± 5.3	0.68 ± 0.05	93.9 ± 3.6
3Ax1A-b	Hybrid (25)	111.9 ± 6.1	48.7 ± 3.5	162.5 ± 4.6	0.69 ± 0.04	92.9 ± 4.2
BMx3A	Hybrid (25)	109.2 ± 7.7	45.9 ± 3.4	161.3 ± 4.5	0.68 ± 0.06	91.7 ± 3.3

Explanation: *) = day after transplanting; ± symbol = standard error

Conclusion

The variations were found in the seedling growth characters, vegetative and reproductive growths in the first year of production cycle of the F1 hybrid populations. F1 hybrids of 2NTBx3A, LBx2NTB, 3Ax2NTB, 3Ax1A, LBx3A, 3Ax1A-b, and BMx3A showed better growth and yield, compared to the other hybrids and their parentals. The growth and the general performance were getting better in the F2 generations in the second year of production cycle. The hybrid of 2NTBx3A and 3Ax1A showed the highest yield potency (98.7 g and 101.1 g, respectively), compared with the other hybrid populations.

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