INITIAL DETECTION OF SENSITIVITY OF UPLAND RICE CULTIVARS UNDER ALUMINUM STRESS

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Abstract

Many factors may be responsible to the limited productivity of upland rice such as, its genetic potential and soil fertility problems. The area of upland-field is usually dominated by ultisol soil which characterized by low nutrients, high acidity and high exchangeable aluminum. Therefore, the use of high quality seeds which especially aluminum tolerance can be regarded as the most appropriate approach to improve the yield of upland rice. The objective of this study was to evaluate the aluminum sensitivity of upland rice cultivars collected in Bengkulu. Research was conducted in the laboratory and greenhouse of the Agronomy Department, the University of Bengkulu from December 2010 to April 2011. Both studies were arranged in a completely randomized design with three replications of each. Seven local cultivars evaluated were Abang Pintal, Bunga Macang, Kancil, Segadang, Kijang, Sedane, and Gemulai. In the first experiment, seeds were germinated in the petridish using germinating paper as a growth media and treated with aluminum at 0.0, 1.0, 2.0, 4.0, and 8.0 mM. Data of germination rates, sprout and root length were collected 2 weeks after germination. The same varieties were also grown in 250-ml plastic pots using ultisol soil as a growth media. Before planted, the media were saturated with aluminum solution at 0.0, 0.5, 1.0, 1.5, and 2.0 mM. The plants were maintained in greenhouse. Data of plant height, shoot and root dry weight were collected at 4 weeks after planting. Data observed were analyzed by analysis of variance and the means were separated by Duncan's multiple ranged test. Based on the root growth of germination experiments, Bunga Macang, Segadang and Gemulai cultivars performed aluminium tolerance or unsensitive to aluminum up to 4.0 mM. However, based on root and shoot dried weight of seedlings, Abang Pintal and Kancil cultivars performed aluminum tolerance or unsensitive to aluminum at 2.0 mM.

Key words: *aluminum, cultivars, tolerance, upland rice.*

Introduction

One constraint in development of upland rice is the availability of high quality of seeds. In Bengkulu province, there are many type of upland rice cultivar grown by the farmer [1]. These cultivars have been able to adapt with local environment and climate. A reason to grow a certain cultivar continously is because the rice it grows has a delicious taste and good aroma. In an early study, 42 local cultivar of upland rice have been collected in the province of Bengkulu [2]. Although local cultivars have sufficiently adapted with local environment in the past, its productivity still remain low. In Indonesia the average production of upland rice is 2.56 ton ha^{-1} where this is far below the production of irrigated rice, 4.78 ton ha^{-1} [3].

Effort to increase upland rice productivity can be done through an exstensification program [4]. The area of dry land which has not been managed in Indonesia yet has reached 35 million ha. This area can become potent for growing upland rice. The widest areas lies in Sumatra Island, Kalimantan, Sulawesi, and West Irian [4]. Dry land which has not been exploited yet is dominated by ultisol soil. In Bengkulu province, 14.3 % from 1,978,870 ha of dry land's soil is ultisol [5]. Some characteristics of ultisol soil are low pH, low capacities to convert cation, saturated of low base, low content of nutrients like N, P, K, Ca, and Mg [4]. In ultisol soil with low pH, some elements like aluminum (Al), manganese (Mn), and iron (Fe) will become toxid to crops. The elements can adsorp nutrients, especially P (phosfor), potassium (K), sulphur (S), magnesium (Mg), and molybdenum (Mo). Hence, that not available to permeated by crop roots [6,7]. If dry land's constraints can be overcome by conducting agronomic techniques and is also supported by the available of pre-eminent seeds, the potency of dry land will help rice production reach its national target [4].

Breeding genetic materials of crops to get pre-eminent seeds should be done in order to increase crop adaptation. Genetics of upland rice that will able to grow at ultisol soil ought to adapt in the situation with extremely high aluminum content [8]. Effort in repair of genetics can be done by exploration, collection and selection of various upland rice cultivar in order to develop aluminum tolerant cultivar. In general, upland rice cultivars are sensitive to aluminum [9]. High content of aluminum have negative effect to the the growth and production of upland rice. The presence of aluminum at 50 ppm in the growth medium may inhibit root growth [6], or damage to root system including the resistant varieties [10,11]. Root damage also reported in other crops such as corn and wheat [12,13].

The symptom in the early growth of tomato affected of aluminum were depression of root growth, chlorosis, deficiencies of nutrients [14]. As a result, crops will become smaller. The major symptom of aluminum toxicity is destroying the growth of root because crop damages by aluminum were found more predominant in parts of root compared to shoot [13, 15, 16]. Other researchers reported the sympthom of aluminum to root such as growing short, thick, reddish or tan and damage of root caps [12]. Aluminum toxicity is one of the major limitation of crop production in dry acid land especially in tropical region [4,6].

There are two mechanism of crops that hinder aluminum toxicity. Firstly, an external mechanism called expulsion of aluminum. The other is an internal mechanism which is the ability of crop physiologically to neutralize aluminum [6,17]. The internal mechanism is related to the presence of organic compound in crop such as oxalat, cittrate, malat, several types of protein, and fenolics which capable to detoxify aluminum [14]. Crops capable to adapt at high aluminum concentration because of the crops have a molecular mechanism to depress the toxic influence of aluminum so there's no disturbance upon the absorption of nutrients, water, and inhibition of aluminum absorbtion and translocation through the crop [10].

Evaluation of crop responces to aluminum at the germination phase or in the early growth can predict the nature of crop tolerance to aluminum. This matter shorten the time of selection to look for more tolerant cultivar. The objective of this experiment is to select the aluminum tolerance at the early growth of upland rice cultivars collected in Bengkulu.

Materials and Methods

Researches to detect aluminum tolerant of upland rice cultivars collected in Bengkulu were conducted in two stages. These researches were is in the laboratory and greenhouse of the Department Agronomy, Faculty of Agriculture, the University of Bengkulu from December 2010 to April 2011. Seven local cultivars of upland rice collected in Bengkulu province in 2009 were used as genetic materials which were Abang Pintal, Bunga Macang, Kancil, Segadang, Kijang, Sedane, and Gemulai [2]. The second factor is aluminum (Al^{3+}) which consist of 5 concentration levels that were 0.0, 1.0, 2.0, 4.0, and 8.0 mM. Further, the experiments at early growth in greenhouse, aluminum concentratations were 0.0, 0.5, 1.0, 1.5, and 2.0 mM. There were 35 treatment combinations in each experiments. Both experiments were arranged in completely randomized design (CRD) and repeated 3 times.

Germination test

Two layers of germination paper which were used as growth media were placed on petridish (diameter of 10 cm). Five seeds of each cultivar of upland rice were planted on the paper media then saturated by 5 ml aluminum solution ($AlCl_3.6H_2O$) at a concentration as according to each treatment. After planting, the petridishes were covered by its lids and placed in the germination room. Humidity inside the petridishes were maintained by media sprayed with water daily. Growth of seeds were observed visually and data of germination rates, root length, and sprout length were collected at 2 weeks after planting. Data were analyzed statistically with analysis of variance (ANOVA) and the means were separated by Duncan's multiple range test (DMRT) at 5 percent.

Seedling growth

The media used for seedling growth is soil of ultisol type. Soil was ground and air dried, sieved at diameter up to 2.0 µm. One day before planting, 200 gram of soil were filled into each of 250 ml plastic pots. Three upland rice seeds were planted into the soil media of each pot with 2 cm deepness. Furadan 3G was added into plant hole to prevent the seeds from insect. Then, the seed holes were covered with soil and arranged in greenhouse by completely randomized design. Then the soil in each pot was saturated with aluminum solution as according to a concentration of each treatment. Seedlings were arranged in greenhouse and maintained based on the standard maintanence in the greenhouse experiments such as, watering as needed, weed control and pest control. Data were collected at 4 weeks after planting including seedling height, root dry weight, and shoot dry weight. Additional data of soil media were analyzed for pH, Al-exchangeable. Data were analyzed statistically by ANOVA and means of each treatment were separated by DMRT at 5 percent.

Result and Discussion

Germination test

Aluminum treatments have affected seed germination of upland rice cultivars collected in Bengkulu province. Visual observation indicated that increasing aluminum up to 8.0 mM will progressively affect the abnormalmality of germination seeds **(Figure 1)**. With the treatment at 8.0 mM aluminum, roots grew below abnormal, short, rust colored (chlorosis), dwindle like burnt, and run dry so that finally die **(Figure 1).**

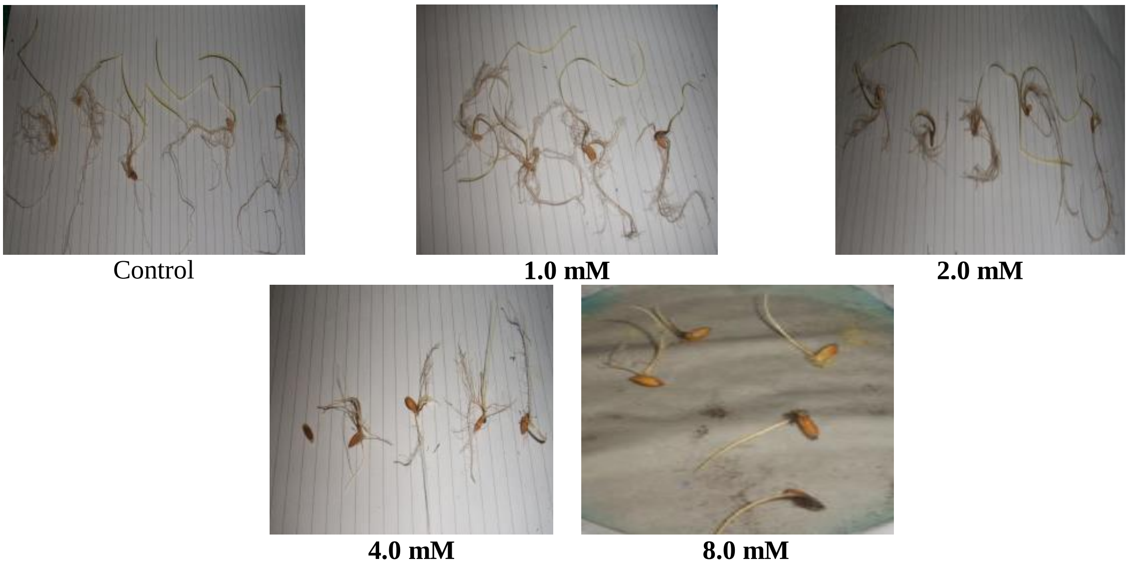

Figure 1. Germination of upland rice seeds of cultivar Abang Pintal with various concentration of aluminum at paper media in petridish.

Saturation of aluminum solution at germination media showed negative effect on germination rate, length of sprout and root. Data of germination rates, length of root and sprout were depicted in graph. Without treatment or control, the germination rate of cultivar Gemulai and Kancil were smaller than 60 percent and these rates were different from other cultivars. By increasing aluminum concentration, the germination decreased to all of tested cultivars. Treatment with 4.0 mM aluminum decreased the germination to 80 percent, and treatment with 8.0 mM aluminum decreased the germination to 60 percent **(Figure 2).**

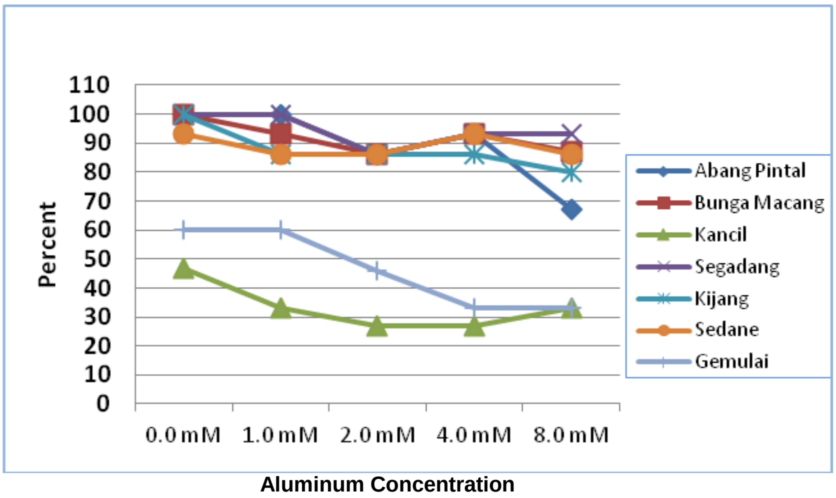

Figure 2. Response of germination rates of upland rice cultivars to different aluminum concentration at 2 weeks.

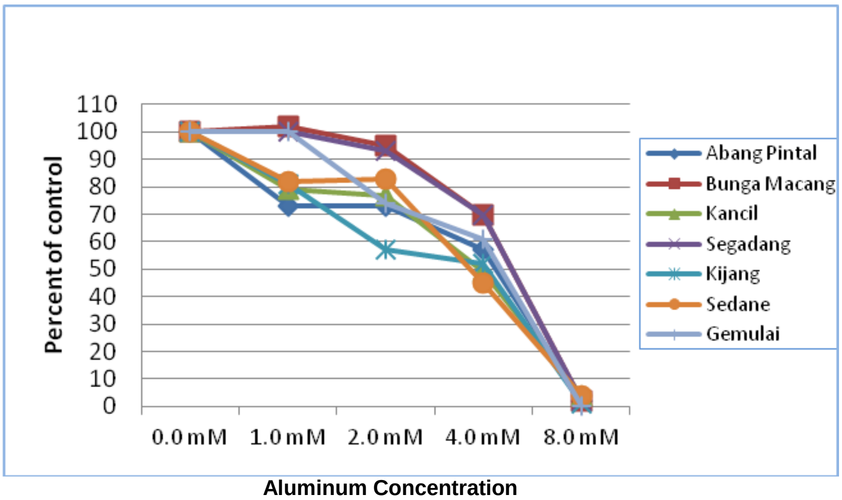

Figure 3. Response of roots lenght of sprout of upland rice cultivars to different aluminum concentration at 2 weeks.

Figure 3 and 4 described the influence of aluminum to the length of root and sprout at 2 week after planting, respectively. Growth of root tend to be more sensitive compared to sprout. Root grew till 4.0 mM aluminum, but at 8.0 mM the root became abnormal and oftenly died. At 4.0 mM aluminum, the root of some cultivars still grew more than 50 percent of control including cultivar of Bunga Macang, Segadang, Gemulai, and Abang Pintal **(Figure 3)**. Different from root, the lenght of sprout of cultivar Kancil, Sedane, Kijang, Bunga Macang, and Gemulai still grew more than 50 percent of control at 4.0 mM aluminum. However, at 8.0 mM the sprout grew lower than 50 percent of control **(Figure 4).**

Seven tested cultivar had been selected and grew well at the field of ultisol soil (pH 4.6 and exchangebale aluminum 5.20 ppm) [2]. These cultivars were clustered to a high productivity group (> 3.8 ton ha^{-1}). The pattern of graph in **Figure 3 and 4** indicates that these seven cultivars were aluminum tolerant because crop response did not show sensitivity at the lowest concentration (1.0 mM). The growth of root can be used as an early indicator for the selection of the most tolerance crop [12]. At a certain aluminum concentration, the greater root length identified that the crop is more tolerant progressively to aluminum [12,15,16].

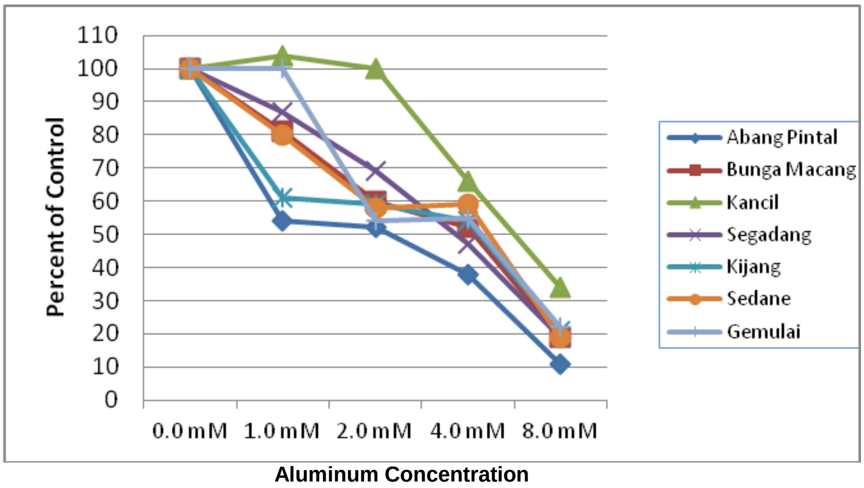

Figure 4. Response of shoot lenght of sprout of upland rice cultivars to different aluminum concentration at 2 weeks.

Each cultivar or crop species have a different reaction to aluminum concentration. This research indicates that some of cultivar still be tolerant in the growth of sprout and root more 50 percent at 4.0 mM aluminum. Previous researchers reported that aluminum at 5.0 mM still pursue growth of paddy root more than 50 percent [10,11].

Seedling growth

Aluminum concentration in this experiment was adjusted for ability of tested cultivar to grow well under the soil media of ultisol and greenhouse condition. Visual observation indicated that saturated of aluminum to the soil media affected the growth of upland rice. Statistical analysis indicated that seedling height, root, and shoot dry weight showed different responses to saturated treatment of aluminum. Result of DMRT test were presented at **Tables 1**, **2**, **and 3**.

Seedling heights at 4 weeks were decreased significantly by increasing aluminum concentration **(Table 1)**. The effects were also different among the examinee cultivars. The data of seedling height were converted to percentage of control. The more tolerant cultivar at 2.0 mM aluminum were Segadang, Abang Pintal, and Kancil where seedling height can still reach 48, 46, and 42 percent of control, respectively while sensitive kultivar such as Kijang, Gemulai, Bunga Macang, and Sedane experienced a height drop to 26, 16, 9, and 8 percen of control, respectively. Also, seedling height at early growth can be used as an indicator of aluminum tolerance. This was anticipated because crop have experienced of injury due to aluminum at the time of early germination.

Injury and stress from aluminum at the early growth may affect on root and shoot biomass. The existence of aluminum at low pH can adsorp essential nutrients to hinder absorbtion of root [9]. Degradation of root dry weight differenciate significantly among examinee cultivars **(Table 2).** At 2.0 mM aluminum, root dry weight of cultivar Abang Pintal, Kancil, Kijang and Gemulai grew more than 50 percent of control. However, Bunga Macang, Sedane and Segadang only grew less than 50 percent of control **(Table 2)**. Dry weight of root biomass also can be used as an indicator to evaluate the nature of aluminum tolerance [9]. Shoot dry weight also showed similar pattern of responce with root dry weight. Shoot dry weight of cultivar Abang Pintal, Kancil, and Segadang were not different between aluminum at 2.0 mM and control **(Table 3).**

This research indicates that the difference of aluminum tolerance of upland rice cultivar were able to be detected since germination and also at an early stage of seedling. This matter has been explained previously by [6,13]. They expressed that sensitivity of crop varietas to negative influence of aluminum was different at the early stage of growth. The difference of sensitivity level between research in laboratory and greenhouse is probably due to the difference of growth medias and environmental factors. In laboratory experiment, the media and environmental factors were more in control. In greenhouse, the media was the ultisol soil (pH 4.4 and exchangeable aluminum 5.29) with diverse environment factors (temperature and humidity). Temperature, humidity, nitrate content, and existence of organism also influenced crop responces to aluminium [6,14].

Conclusion

1. Cultivar tested were able to germinate more than 50 percent at 8.0 mM aluminum.
2. Cultivar of Bunga Macang, Segadang, and Gemulai were aluminum tolerance indicated by the growth of root lenght at 4.0 mM aluminum which were 70, 70, and 61 percent of control, respectively; while based on sprout length, cultivar Kancil, Sedane, and Gemulai were aluminum tolerance indicated with the sprout length at 4.0 mM aluminum which were 66, 59, and 55 percent of control, respectively
3. Cultivar of Segadang, Abang Pintal and Kijang were aluminum tolerant in ultisol media indicated by the shoot lenght of seedling in 2.0 mM aluminum which were 48, 46, and 42 percent of control, repectively. Cultivar of Abang Pintal and Kijang were nature aluminum tolerant because root and shoot dry weight of seedlings were not different significantly from control at the treatment of 20 mM aluminum.

Tabel 1. Response of seedling height of upland rice cultivars to different aluminum concentration at 4 weeks after planting *

Cultivar	Seedling height at :				
	Control	5.0 mM	1.0 mM	1.5 mM	2.0 mM
	------------- cm / plant (*percent of control*) ----------------				
Abang Pintal	31.36 ^{abc}	19.30 ^{ghi}	20.23 ^{ghi}	11.60 ^{mno}	14.46 ^{jkl}
	(100)	*(62)*	*(65)*	*(37)*	*(46)*
Bunga Macang	28.33 ^{abc}	25.46 ^{cde}	21.56 ^{fgh}	14.56 ^{jkl}	2.63 ^{q}
	(100)	*(90)*	*(76)*	*(51)*	*(9)*
Kancil	25.83 ^{bcd}	21.03 ^{fgh}	20.96 ^{fgh}	10.86 ^{nop}	10.96 ^{nop}
	(100)	*(81)*	*(81)*	*(42)*	*(42)*
Segadang	28.83 ^{abc}	22.10 ^{fgh}	18.73 ^{ghi}	15.66 ^{ijk}	13.73 ^{klm}
	(100)	*(77)*	*(65)*	*(54)*	*(48)*
Padi Kijang	35.00 ^{a}	21.33 ^{fgh}	12.70 ^{lmn}	11.00 ^{nop}	8.96 ^{opq}
	(100)	*(61)*	*(36)*	*(31)*	*(26)*
Sedane	33.33 ^{ab}	22.63 ^{efg}	16.76 ^{hij}	15.36 ^{ijk}	2.80 ^{q}
	(100)	*(68)*	*(50)*	*(46)*	*(8)*
Padi Gemulai	31.90 ^{abc}	23.86 ^{def}	16.30 ^{hij}	9.93 ^{opq}	5.00 ^{qp}
	(100)	*(75)*	*(51)*	*(31)*	*(16)*

* Numbers which following by the same letters showed no difference at DMRT 5%

Tabel 2. Response of root dry weight of upland rice cultivars to different aluminum concentration at 4 weeks after planting *

Cultivar	Root dry weight at :				
	Control	0.5 mM	1.0 mM	1.5 mM	2.0 mM
	-------------------- (gram / plant) ----------------------				
Abang Pintal	0.43 ^{ijk}	0.46 ^{ijk}	0.47 ^{ij}	0.39 ^{ijk}	0.46 ^{ijk}
Bunga Macang	0.49 ^{i}	0.45 ^{ijk}	0.47 ^{ij}	0.45 ^{ijk}	0.11^{q}
Kancil	0.43 ^{ijk}	0.46 ^{ijk}	0.46 ^{ijk}	0.45 ^{ijk}	0.41^{ijk}
Segadang	0.41 ^{ijk}	0.33 ^{lmn}	0.31^{nop}	0.34 ^{lmn}	0.23 ^{p}
Padi Kijang	0.42 ^{ijk}	0.38 ^{jkl}	0.32 ^{mno}	0.33 ^{lmn}	0.34 ^{lmn}
Sedane	0.36 ^{klm}	0.36 ^{klm}	0.37 ^{jkl}	0.24 ^{op}	0.13 ^{pq}
Padi Gemulai	0.36 ^{klm}	0.39 ^{ijk}	0.36 ^{klm}	0.37 ^{jkl}	0.31^{nop}

* Numbers which following by the same letters showed no difference at DMRT 5%

Tabel 3. Response of shoot dry weight of upland rice cultivars to different aluminum concentration at 4 weeks after planting *

Cultivar	Shoot dry weight at :				
	Control	0.5 mM	1.0 mM	1.5 mM	2.0 mM
		------------------	(gram / plant)	-------------------	
Abang Pintal	0.28 jkl	0.22 klm	0.22 klm	0.21 lmn	0.20 lmn
Bunga Macang	0.31 jk	0.24 klm	0.20 lmn	0.20 lmn	0.15 nop
Kancil	0.20 lmn	0.19 lmn	0.20 lmn	0.28 jkl	0.28 jkl
Segadang	0.29 jkl	0.24 klm	0.23 klm	0.22 klm	0.21 klm
Padi Kijang	0.33 j	0.21 klm	0.24 klm	0.28 jkl	0.20 lmn
Sedane	0.29 jkl	0.21 lmn	0.16 nop	0.18 mno	0.12 pq
Padi Gemulai	0.28 jkl	0.21 klm	0.14nop	0.09 q	0.13 opq

* Numbers which following by the same letters showed no difference at DMRT 5%

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