Syngenta's Actigard 50WG

Plant Growth Regulator as a Potential

Export Idea to Nepal

Cody Lemon

AGR*1110

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Agriculture in Nepal is a predominant sector, employing 70% of their population and controlling over 33% of their GDP (CIA, 2015). Tomato production in Nepal is a major part of this agricultural sector with 10 000 hectares of land being used for tomato production, averaging 72 000 tonnes of yield per year (Lamichhane et al. 2010). Bacterial spot and bacterial speck disease in tomatoes are major yield limiting factors in Nepal due to the wet, humid climate (Lamichhane et al. 2015). Nepal farmers need to reduce tomato yield losses to maximize their profit and controlling these diseases will do just that. Syngenta's Actigard^{TM} 50WG Plant Growth Regulator is used on tomatoes to prevent bacterial spot and bacterial speck disease (Syngenta, 2015) and is a great product for Nepalese tomato farmers.

Part 1 – Syngenta's Actigard^{TM} 50WG Plant Growth Regulator

Syngenta's Actigard^{TM} 50WG plant Growth Regulator is a non-pesticidal systemic compound used on tomatoes to control bacterial spot and bacterial speck (Syngenta, 2015). The active ingredient, Acibenzolar-S-methyl, boosts the plants natural defense system known as the systemic activated resistance (SAR) to fight off these diseases which makes this product different from normal fungicides and bactericides (Syngenta, 2015). The mode of action is in the category of Host Plant Defense Induction, Group P1 because of its natural defense qualities within the plant and actually has no direct effect on the disease (Syngenta, 2015). The active ingredient, Acibenzolar-S-methyl is an important asset in reducing bacterial speck and bacterial spot in tomatoes in an organic manner (Louws et al. 2001).

Bacterial Spot & Bacterial Speck

Bacterial spot is caused by the *Xanthomonas campestris pv. vesicatoria* organism which is present in optimum temperatures of 24-30°C (OMAFRA, 2015). This disease causes lesions

on the parts of the plant that are aboveground and results in small, dark, circular lesions surrounded by a yellow halo usually on the edge of the leaves (figure 1) (OMAFRA, 2015). Small, dark spot lesions sometimes surrounded by a white halo occur on the green fruit and can increase to 4-6mm in diameter (figure 2) (OMAFRA, 2015). The source of this disease is located in the seeds and infected crop residue but can also be present on volunteer tomato plants along with equipment (OMAFRA, 2015).

Fig 1. (left) Leaf lesions caused by bacterial spot (OMAFRA, 2015).

Fig 2. (right) Fruit lesions caused by bacterial spot (OMAFRA, 2015).

Bacterial Speck is caused by the *Pseudomonas syringae pv. tomato* organism which is present in optimum temperatures of 18-24°C (OMAFRA, 2015). This disease also causes lesions on the plant occurring on the foliage, stems, or fruit with symptoms very similar to bacterial spot (OMAFRA, 2015). Black specks usually surrounded by a yellow halo as seen in figure 3 occur on the leaves making leaf tissue unable to expand (OMAFRA, 2015). This causes the leaf to deform and much like bacterial spot, these lesions generally occur near the edges of the leaf (OMAFRA, 2015). Green fruit can only be affected by this disease causing small black specks on the tomato as seen in figure 4 (OMAFRA, 2015). This disease can be present in the crevices

and cavities of the tomato seed coat for up to 20 years and when bacterial speck gets very serious, seedling growth can be stunted (OMAFRA, 2015).

Fig 3. (left) Leaf lesions caused by bacterial speck (OMAFRA, 2015).

Fig 4. (right) Fruit lesions caused by bacterial speck (OMAFRA, 2015).

When these diseases are present within a crop they can be spread by splashing water and moving precipitation during storms (OMAFRA, 2015). These diseases require moisture which can be caused by rain, humidity, irrigation, and even fog (OMAFRA, 2015). It has been proved that in high temperatures, disease severity also increased, but when humidity is decreased disease severity also decreased (Yunis et al. 1980). Irrigation actually increases humidity and helps spread the disease which increases overall foliage of the plant (Yunis et al. 1980). It has also been proven that the younger the crop is when the disease becomes present the more yield is lost as seen in figure 5 (Yunis et al. 1980). When the optimum temperatures are met and adequate moisture is present, farmers can see up to a 60% yield loss (OMAFRA, 2015).

Time after planting (mo)	Location, cultivar	Treatment	Yield (ton/1,000 m²)[w]	Percent of control
1	Sandala, Orit Early spring 1979	Control Copper hydroxide	2.107 a 2.940 b[x]	100 175
2	Tamra, Orit Early spring 1978	Control Copper hydroxide	5.020 a 6.330 b[x] 6.208 b[y] 6.281 b[z]	100 126
3	Tamra, VF-134—1-2	Control Copper hydroxide	6.360 a 6.840 a[x]	100 107

[w] Each experiment was statistically analyzed separately. Numbers followed by different letters are significantly different ($P = 0.05$) by Duncan's multiple range test.
[x] 0.5% weekly sprays.
[y] Sprays every 2 wk.
[z] Sprays after rain or irrigation.

Fig 5. Effects on tomato yield based on the age that crop was infected with bacterial speck (Yunis et al. 1980).

Application Process

Syngenta's Actigard 50WG Plant Growth Regulator is a water soluble compound that is mixed at a 10 gram per 10 gallon per acre ratio (Syngenta, 2015). This small tank mix would allow for a hand sprayer to be used by farmers that cannot afford a tow-behind sprayer as long as safety clothing is worn. When mixing the spray, make sure that the equipment is properly cleaned and mix the exact amount that is going to be used for spraying, do not let a spray mix sit overnight (Syngenta, 2015). To properly create the tank mix, pour half of the required water in, then add the Actigard^{TM} 50WG while stirring and then add the rest of the water while continuing to stir the mix (Syngenta, 2015). The first application of this product should be done at least 7 days after transplant before the bacterial diseases appear (Syngenta, 2015). After the first application, prior applications should be done on a week to week schedule before the disease can develop (Syngenta, 2015). Applications should not occur when plants are stressed from drought, excessive precipitation, cold weather, along with other stresses, and a maximum of 8 applications per season is recommended (Syngenta, 2015).

Syngenta

Syngenta is a world leading agricultural company located within 90 countries focusing on crop productivity and the environment (Syngenta, 2015). Within Canada, Syngenta has businesses throughout the provinces that are associated with seeds, seed care, lawn/garden care, and crop protection (Syngenta, Canada). Within the crop protection sector, Syngenta focuses on maximizing yield by protecting crops from disease, insects, and weeds (Syngenta, 2015). They create products that are effective at low rates and when a new product is released in Canada it is heavily reviewed by Health Canada to ensure safety (Syngenta, 2015). The Actigard^{TM} 50WG Plant Growth Regulator was created in the crop protection sector and is the only plant growth regulator that Syngenta Canada has listed (Syngenta, 2015). Its unique mode of action sets it apart from other fungicides and bactericides used today (Syngenta, 2015).

Benefits to Canada

Syngenta Canada is a trusted agricultural company that is known to produce safe and effective products (Syngenta, 2015). The Actigard^{TM} 50WG Plant Growth Regulator was discontinued across Canadian markets after October 2015 (Filotas, 2015). This decision was made by Syngenta due to declining sales across Canada, however Syngenta will still own the registration of this product (Filotas, 2015). Since Syngenta owns the right to this product no other company will have a product with the same active ingredient making the market non-competitive for Syngenta. Therefore if Syngenta can provide a market for this product in Nepal there will be an obvious benefit. Syngenta will be able to continue extensive production of the Actigard^{TM} 50WG Plant Growth Regulator to regain the profit lost in the Canadian market.

Continuing and increasing production of Actigard^{TM} 50WG will increase the amount of jobs within Syngenta and may increase the amount of research facilities within Canada. The company should increase in size and become wealthier while increasing the overall economy in Canada.

Part 2 – Export Potential to Nepal

Nepal

Nepal is a small country of 147 181 square kilometers in Southern Asia located between China and India (CIA, 2015). Nepal is located about 11 000 kilometers away from Canada with a land area 64 times smaller than Canada but a population only 1.2 times smaller (CIA, 2015). One-quarter of the population is under the poverty line and agriculture is a very important part of the economy employing 70% of Nepal and controlling over 30% of their GDP (CIA, 2015). Agricultural land controls 28.8% of the land where 15.1% is arable land, 1.2% is permanent crops, and 12.5% is permanent pasture (CIA, 2015). As you can see, Nepal is a poor, densely populated country that relies heavily on agricultural production.

Agro-ecological Regions

Nepal is made up of 3 agro-ecological regions; the mountains, the hills, and the Terai region (Pariyar, 1998). The Terai region consists of flat land ranging from 60 to 300m in elevation and a climate consisting of tropical to sub-tropical (Pariyar, 1998). The temperature in the Terai region ranges from 7-24°C in December/January and 24-41°C in June/July (Pariyar, 1998). The rainfall in the Terai region ranges from 600-1300mm (Pariyar, 1998). The Terai region is the most important region for agricultural production due to its tropical climate and flat land making it possible to grow a variety of crops (Pariyar, 1998).

The hills region consists of land ranging from 300 to 2000m in elevation and has a cooler climate compared to the Terai region (Pariyar, 1998). The temperature in the hills region ranges from 2-17°C in December/January and 13-27°C in Jun/July (Pariyar, 1998). The rainfall in the hills region ranges from 1000-2800mm (Pariyar, 1998).

The mountain region has the highest elevation of 2000m and above which results in the coolest climate of the three regions (Pariyar, 1998). The temperature in the mountain region ranges from 9-10°C in June/July and the average rainfall ranges from 140-900mm (Pariyar, 1998). Any agriculture done in these areas are located in low lying areas and a very low variety of crops can be produced here (Pariyar, 1998).

Tomatoes in Nepal

Tomatoes are very important within the agricultural industry in Nepal with over 10 000 hectares of land being used, yielding 72 000 tonnes on average per year (Lamichhane et al. 2010). The difference in the agro-ecological regions play a huge role on where certain crops can be produced and because of these differences, tomatoes can be produced year round (Lamichhane et al. 2010). The Terai region can produce tomatoes in winter, spring, and within the rainy seasons while the hill region can produce tomatoes in the spring and summer months (Lamichhane et al. 2010). With so much land used for tomato production in Nepal, maximizing yields are very important to get the most efficient use of the land.

Bacterial Tomato Diseases in Nepal

Nepal has a very diverse climate with a high amount of precipitation and high temperatures during the summer and fall months making bacterial diseases very predominant (Syngenta, 2015). Many cultivars of tomatoes have been tested in Nepal to observe the responses

to bacterial speck within the different cultivars and as seen in figure 6 there were many differences (Lamichhane et al. 2010). It can be seen in figure 6 that Thims 16 and C.L cultivars had the lowest disease severity index (DSI) and for this reason these cultivars are recommended for use in Nepal (Lamichhane et al. 2010). The majority of tomato crops are grown outdoors in Nepal and when the climate is favourable for bacterial diseases, every cultivar will show major economic losses (Lamichhane et al. 2010). Bacterial speck is a major yield limiting factor in both spring and summer cultivars in Nepal and must be controlled to lower the economic losses Nepalese farmers are experiencing within tomato production (Lamichhane et al. 2010).

Cultivar	DSI in the field ± SE			DSI in the tunnel ± SE		
Thims 16	1.80	bc*	±0.20	3.45	fghi*	±0.17
C.L.	2.05	bcd	±0.23	1.10	a	±0.10
Spectra 737	2.25	cd	±0.19	2.90	ef	±0.20
Bishesh	2.60	de	±0.20	3.05	efgh	±0.21
B.L.	3.00	efg	±0.25	1.65	ab	±0.18
NS-719	3.05	efgh	±0.18	4.20	jk	±0.21
Panjabi	3.55	ghi	±0.22	1.20	a	±0.12
Srijana	3.60	ghi	±0.17	3.60	ghi	±0.18
Manisha	3.65	hij	±0.17	3.75	ijk	±0.16
Lapsi Gede	4.25	k	±0.22	2.30	cd	±0.21

* Means followed by the same letter are not significantly different at P=0.05.

Fig 6. Disease severity index (DSI) within different tomato cultivars 10 days after inoculation with bacterial speck disease (Lamichhane et al. 2010)

Benefits to Nepalese Farmers

Syngenta's Actigard™ 50WG Plant Growth Regulator would be a great product for use in Nepal due to the fact that it can protect tomato crops from disease within a hot, wet climate (Syngenta, 2015). This product will bring a new approach to disease management by boosting

the plants natural defense system and in turn reducing yield losses (Louws et al. 2001). Many field tests have been done within Florida, Alabama, North Carolina, Ohio, and Ontario that prove that Actigard™ 50WG is very effective compared to standard bacterial control treatments (figure 7 & 8) (Louws et al. 2001). Actigard 50WG did not just reduce the severity of bacterial spot and bacterial speck but it also increased yield in multiple cases (figure 7 & 8) (Louws et al. 2001). Overall Actigard 50WG was proven to be effective in all 5 regions when applied at an optimum rate and a constant schedule reducing plant foliage (Louws et al. 2001).

Exp. no.	Treatment	Foliar severity of bacterial spot[x]	Fruit with bacterial spot[x]	Yield mt/ha	Yield % of control	Comments[y]
1	Control	50.9	...	9.3		Auburn 1996
	Standard	50.6	...	7.8	83.9	Agriset 761
	Actigard	42.5**	...	10.3	110.8	% defoliation
2	Control	174.4	3.7	119.0[z]		Auburn 1996
	Standard	92.6*	3.3	77.0	64.7	Agriset 761
	Actigard	78.9*	2.6	83.5	70.2	AUDPC
3	Control	232.1	...	21.7		Auburn 1997
	Standard	109.6*	...	38.0	175.1	Rutgers
	Actigard	71.5**	...	32.2	148.4	AUDPC
4	Control	1,346.7	...	...		Auburn 1997
	Standard	848.2*	...	...	...	Agriset 761
	Actigard	526.9**	...	...	...	AUDPC
5	Control	692.6	29.4	31.3		Auburn 1998
	Standard	411.3*	27.6	35.2	112.5	Agriset 761
	Actigard	334.4*	20.2**	36.0	115.0	AUDPC
6	Control	239.7	30.0	59.5		Ontario 1997
	Standard	...	...	...	...	Heinz 9478
	Actigard	76.8*	22.6	66.7	112.1	lesions/20-leaf sample
7	Control	254.0	47.0	21.6		North Carolina 1996
	Standard	179.0*	29.0*	29.0	134.3	Solar Set
	Actigard	129.0**	26.0*	22.1	102.3	AUDPC
8	Control	169.0	39.0	55.2		North Carolina 1996
	Standard	140.0*	20.0*	54.8	99.3	SunLeaper
	Actigard	101.0*	15.0*	49.2	89.1	AUDPC
9	Control	205.7	16.2	44.6		North Carolina 1997
	Standard	123.5*	6.7*	37.3	83.6	Solar Set & SunLeaper
	Actigard	147.7*	6.4*	43.0	96.4	AUDPC
10	Control	...	1.6	17.5		North Carolina 1998
	Standard	...	0.0	18.6	106.3	Solar Set & SunLeaper
	Actigard	...	0.4	16.4	93.7	AUDPC
11	Control	111.8	1.5	49.4		Ohio 1997
	Standard	56.8*	1.6	52.2	105.6	OH7814
	Actigard	63.3*	0.4	45.7	92.6	AUDPC
12	Control	33.3	14.0	37.9		Ohio 1998
	Standard	6.3*	3.4*	44.1	116.4	Peto 696
	Actigard	5.0*	6.7*	27.7	73.1	% disease 2 Sep
13	Control	44.3	>0.1	64.7		Ohio 1999
	Standard	19.0*	>0.1	71.1	109.9	Peto 696
	Actigard	26.1	>0.1	59.7	92.3	% disease 30 Aug
14	Control	97.8	...	40.4		Florida 1996
	Standard	48.6*	...	43.7	108.2	Agriset 761
	Actigard	44.4*	...	31.9	79.0	AUDPC
15	Control	99.6	...	19.3		Florida 1997
	Standard	76.4*	...	22.6	117.1	Sunbeam
	Actigard	63.4*	...	18.5**	95.9	AUDPC

[x] Values followed by * are significantly different ($P = 0.05$) than control plots; means followed by ** are significantly ($P = 0.05$) different than the standard bactericide treatment and control plots based on Duncan's multiple range test (AL, FL, ON) and Fisher's protected least significant difference (OH, NC).
[y] Comments highlight location and year of experiment, tomato cultivar, and method of scoring foliar disease severity.
[z] Values are number of fruit per plot, not mt/ha.

Fig 7. Actigard™ 50WG effect on bacterial spot infected tomato crops compared to standard bactericide treatments (Louws et al. 2001).

Exp. no.	Treatment	Foliar severity of bacterial speck[v]	Fruit with bacterial speck[v]	Yield mt/ha	Yield % of control	Comments[w]
16	Control	1.3	...	...		Auburn 1997
	Standard	1.1*	...	...	...	Agriset 761
	Actigard	1.0*	...	...	...	Log no. lesions/leaflet
17	Control	1.4	...	...		Auburn 1997
	Standard	0.9*	...	...	...	Agriset 761
	Actigard	0.8**	...	...	...	Log no. lesions/leaflet
18	Control	35.3	...	...		Auburn 1998
	Standard	30.4	...	...	...	Agriset 761
	Actigard[x]	22.6*	...	...	...	% final disease severity
19	Control	44.3	...	...		Auburn 1998
	Standard	26.1	...	...	...	Agriset 761
	Actigard	19.7*	...	...	...	% final disease severity
20	Control	45.0	22.6	87.8		Ontario 1997
	Standard	...	...	...	...	Heinz 9478
	Actigard	10.5*	16.1*	83.2	94.8	Lesions/20-leaf sample
21	Control	...	9.2	17.3[y]		North Carolina 1998[z]
	Standard	...	...	...	...	Mountain Fresh (foliar
	Actigard	...	1.4**	12.6**	72.8	incidence not rated)
22	Control	2.1	12.5	22.7[y]		North Carolina 1999
	Standard	5.3*	21.1*	21.2	93.4	Mountain Spring
	Actigard	0.0**	7.0	29.5**	130.0	% leaf area damaged

[v] Values followed by * are significantly different ($P = 0.05$) than control plots; means followed by ** are significantly ($P = 0.05$) different than the standard bactericide treatment and control plots based on Duncan's multiple range test (AL, FL, ON) and Fisher's protected least significant difference (OH, NC).
[w] Comments highlight location and year of the experiment, tomato cultivar, and method of scoring foliar disease severity.
[x] Acibenzolar-*S*-methyl rate was 26.3 g a.i./ha, not 35 g a.i./ha.
[y] Marketable yield.
[z] Acibenzolar-*S*-methyl was applied alone without any fungicides; final percent defoliation due to early blight, late blight, and bacterial speck was 88.9% in plots not sprayed, 85.4% in acibenzolar-*S*-methyl sprayed plots, and 5.3% in the fungicide only plots (mancozeb alternated with azoxystrobin; no bactericide).

Fig 8. Actigard™ 50WG effect on bacterial speck infected tomato crops compared to standard bactericide treatments (Louws et al. 2001).

Therefore Nepalese farmers should find a great benefit from the use of Syngenta's Actigard™ 50WG Plant Growth Regulator. The climate in Nepal causes a great risk for bacterial disease in tomato crops and needs to be controlled effectively. With a tank mix of only 10 grams per 10 gallon per acre ratio (Syngenta, 2015) it makes it very possible to use a hand sprayer for farmers that do not own a tow-behind sprayer. With proper use this product has been proven effective (Louws et al. 2001) and should have the same effect where the climate causes even more susceptibility to bacterial diseases such as Nepal. Nepalese tomato farmers should see a decrease in plant foliage, an increase in yield, and an increase in overall profit.

Transportation and Distribution

Actigard™ 50WG comes in 220g packages (Syngenta, 2015) and because of this multiple packages can be shipped at one time. A1 Freight Forwarding ships internationally from

Toronto to Kathmandu, Nepal (A1 Freight Forwarding, 2015). It is estimated by weight that if multiple packages are shipped within boxes that each unit could be shipped for about 80 cents CAD (A1 Freight Forwarding, 2015). This product will be purchased by a central agricultural dealer within Nepal for distribution to Nepalese tomato farmers. Therefore once the product has reached Kathmandu, Nepal it will have to be transported to this dealer by animal or vehicle. The price of this product at Keystone Pest Solutions LLC. can be purchased online for $277.95 US (Keystone Pest Solutions, 2015) but Syngenta would have to make a trade agreement with Nepal for the exact price that these agricultural dealers would be buying the product for including shipping costs. After this agreement was reached, the central agricultural dealer would have to sell this product to farmers at a higher price to earn profit.

Unknowns

There are still lots of unknown aspects about this product and the details that come along with the trade agreement between Syngenta Canada and Nepal. Transportation details from Toronto to Kathmandu, Nepal were only an estimation based on weight but exact cost would have to be calculated. Also, when the product reaches Nepal it still needs to be transported to an agricultural dealer which is an added transportation expense that would have to be paid by either Syngenta or the agricultural dealer.

The cost of this product found was only from the online Keystone Pest Solutions LLC. store but since this trade agreement would be directly associated with Syngenta Canada a price would have to be agreed between the two parties. The price of this product would have to include transportation costs and any other regulatory costs that are involved.

Use of Actigard™ 50WG Plant Growth Regulator in Nepal has not yet been tested and therefore it is unknown the exact effects that this product will have on tomatoes. It has been proven effective in many other regions but proper use of the product would have to be ensured to obtain the best results mimicking previous research. A variation of climate and cultivars used will probably show different bacterial and yield responses.

Competitive Products

Syngenta's Actigard™ 50WG Plant Growth Regulator is a very unique product because of its mode of action but there are other treatments that are used to try and provide the same crop protection. Copper bactericides have been the major source of control for bacterial spot and bacterial speck in tomatoes but resistant strains have become a major issue (Jones et al. 1991). These copper treatments have been proven very effective with bacterial speck in reducing infection, disease severity, and increasing tomato yield as seen in figure 9 (Yunis et al. 1980). Actigard™ 50WG is actually recommended to use in a tank mix with copper to maximize the products effect (Syngenta, 2015) and it has been proven that doing this does in fact increase the results (Louws et al. 2001). There have been many incidents with copper resistance in tomato crops and sometimes applying copper treatments have increased disease severity (Louws et al. 2001). Also because Actigard™ 50WG has no direct effect on the diseases, pathogen resistance will most likely not occur making this more effective compared to copper treatments (Syngenta, 2015).

Treatment	Disease index at harvest	Plant height[z] (cm)	Dry weight[z] (g)	Fruit disease index[z]	Percent diseased fruits[z]
Control	1.5 b	22.1 b	20.0 b	1.05	52
Copper hydroxide, 0.5%	0.25 a	35.7 a	48.2 a	0.32	26
Copper oxychloride, 0.4%	0.65 a	32.4 b	55.5 a	0.8	53

[y] Experiment was performed in Sandala, cv. Orit, early spring 1979, at random blocks in five replicates. Different letters in the same column represent significant differences at $P = 0.05$.
[z] Measurements at harvesting time. Plant height represents means of 20 plants from each plot. Dry weight represents means of five plants from each plot dried at 80 C for 1 wk. Fruit disease index and percent of diseased fruits represent measurements of 100 fruits selected at random from each plot.

Fig 9. Copper compound effects on bacterial speck (Yunis et al. 1980).

Discussion

After the evaluation of Syngenta's Actigard^{TM} 50WG Plant Growth Regulator as an export from Canada to Nepal it has been proven that this product is very effective in regions with wet, hot climates. Nepal's climate makes the spread of diseases such as bacterial spot and bacterial speck very predominant. Controlling these diseases with Actigard^{TM} 50WG has been proven to be more effective than copper treatments and because of the unique mode of action, pathogen resistance to this product is very unlikely. With an increase in copper resistance among bacterial pathogens, a switch to Actigard^{TM} 50WG is very necessary to protect tomato crops. The price of this product should be affordable for the average Nepalese tomato farmer as no extra equipment is needed besides a hand sprayer. One 220 gram package can be used to spray 2.75 acres of tomatoes for the maximum 8 applications making it very efficient for Nepalese farmers.

In conclusion Nepal and Syngenta Canada should come to a trade agreement providing agricultural dealers with Actigard^{TM} 50WG Plant Growth Regulator. This will provide Nepalese farmers with crop protection for their tomato crops against bacterial spot and bacterial speck that have been reducing yield primarily in climates similar to Nepal's. Syngenta will find a market in Nepal for a product that was recently discontinued in Canada and will produce more jobs within Syngenta.

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