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TOLERANCE of COTTONWOOD to CERTAIN HERBICIDES

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Tolerance of Cottonwood to Certain Herbicides[1]

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INTRODUCTION

THE DECREASING SUPPLY of cottonwood (*Populus deltoides* Bartr.) to meet the demands of pulp and paper and lumber industries has stimulated considerable interest in the cultivation of this species.

Natural regeneration of cottonwood occurs mainly on bare, moist, mineral soil such as new bars and silt deposits along major rivers *(12,21)*. Current river stabilization and flood control measures have greatly reduced natural sites for cottonwood reproduction, thus indicating a future shortage of cottonwood. Artificial regeneration practices must be perfected if future demand for this species is to be met.

Cottonwood can be easily reproduced vegetatively from cuttings if the weed and grass competition is controlled during the first growing season *(20)*. Presently, grass and weed competition is eliminated by mechanical methods such as cross-disking, row plowing, and hand hoeing *(20)*. Control of competing vegetation with herbicides offers an opportunity to reduce regeneration cost if the chemicals do not cause appreciable injury to the cottonwood.

Several workers have used herbicides with variable results for first year weed control in cottonwood *(2,7,10,16,17,23,28)*. Research workers in the Mississippi River Delta have reported poor results from the use of herbicides for weed control in cottonwood *(15,19,22)*.

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A number of new effective agronomic herbicides are now available and this study was conducted to determine the tolerance of cottonwood to certain pre- and postemergence herbicides at varying rates so that field studies might be limited to those compounds which are not injurious to cottonwood.

MATERIALS AND METHODS

Preemergence Herbicides

Preemergence screening studies were conducted at the Auburn Forest Nursery. The soil in the nursery is a sandy loam and has been in nursery production for 13 years.

In March, 1964, 20-inch cottonwood cuttings of Mississippi origin were planted in plots of 10 trees each spaced at 1 × 2 feet. Ten herbicides were applied, each at four rates with four replications. All preemergence treatments were applied on March 23, one week after the cuttings were planted. Heavy rainfall occurred soon after treatment with an accumulation of 26 inches in the first 30 days following spraying; overhead irrigation was used after May 1 to ensure at least 1 inch of water per week on the plots.

Each of four nursery beds was divided into 40 plots. The 40 plots within each bed or block were divided into 10 groups of 4 and herbicides were assigned at random to one of the 10 groups. The rates were: 0 (control), X (a rate which might normally be used in agronomic crops), 2X and 4X. The experimental design allowed each herbicide to be tested as a separate experiment with a check plot for each herbicide.

During the growing season plots were cultivated twice and sprayed twice with paraquat (1,1′-dimethyl-4,4′-bipyridinium salt) to control nut-sedge. The paraquat was applied with a hand sprayer and was directed away from the cottonwood. Complete weed control was practiced to ensure a minimum of competition for the trees so that toxicity of the herbicides could be properly evaluated.

Height measurements and survival counts were made in November, 1964. The trees were cut back to 4 inches above the ground line and allowed to resprout the following year. Survival and height measurements of the sprouts were taken in October, 1965, to determine if there was any residual effect resulting from leaching that might appear the second year after treatment.

The following chemicals and rates were applied by a hand sprayer in the 1964 screening study:

Chemical	*Rate Lb./A.*
Atrazine 80 W (2-chloro-4-ethylamimo-6-isopropylamino-*s*-triazine)	0,3,6,12
Simazine 80W (2-chloro-4,6-bis(ethylamino)-*s*-triazine)	0,3,6,12
EPTC 6 lb./gal. (ethyl *N*, *N*-diproply-thiocarbamate)	0,4,8,16
Norea 80W (3-(hexahydro-4,7-methanoindan -5 yl)-1,1-dimethylurea)	0,1,2,4
Trifluralin 4 lb./gal. (*a,a,a*-trifluoro-2,6-dinitro-*N,N*-dipropyl-*p*-toluidine)	0,.75,1.5,3
Dichlobenil 50W (2,6-dichlorobenzonitrile)	0,4,8,16
Diuron 28% (3-(3,4-dichlorophenyl)-1,1-dimethylurea)	0,1,2,4
Chloroxuron 50W (*N*-(4-chlorophenoxy) phenyl-*N,N*-dimethylurea)	0,1,2,4
Fenac 1½ lb./gal. (2,3,6-trichloro-phenylacetic acid)	0,4,8,16
Picloram 22K (4-amino-3,5,6-trichloro-picolinic acid)	0,1,2,4

All rates in this and later studies refer to active ingredients.

In 1965, additional screening studies were conducted. Diuron was retested in 1965 to determine if true results were obtained in the 1964 study. Dichlobenil and trifluralin are both volatile materials and might have been lost from the soil surface during the first season. Therefore, dichlobenil was applied as a granular formulation and trifluralin was incorporated. Also several additional compounds were tested. The planting stock used in 1965 was collected along the Alabama River in Clarke County, Alabama. The experimental design was the same as for the previous study except that eight herbicides at three rates were used.

These plots had been fumigated with methylbromide the year before, therefore, only one cultivation was necessary to provide

nearly weed free conditions. The plots were irrigated during the growing season. Survival and height measurements were taken in October, 1965.

All measurements from both the 1964 and 1965 studies were analyzed by the analysis of variance.

The treatments included in the second year's screening were:

Chemical	*Rate* *Lb./A.*
Dichlobenil 4-G	0,8,16
Diuron 80W	0,2,4
Trifluralin (unincorporated) 4 lb./gal.	0,2,4
Trifluralin (incorporated) 4 lb./gal.	0,2,4
Diphenamid 80W (*N*,*N*-dimethyl-2,2-diphenylacetamide)	0,8,16
Daxtron 1.5 lb./gal. (2,3,5-trichloro-4-pyridinol)	0,2,4
Sindone 2 lb./gal. (1,1-dimethyl-4,6-diisopropyl-5-indanyl ethyl ketone and 1,1-dimethyl-4,6-diisopropyl-7-indanyl ethyl ketone)	0,6,12
DNBP 3 lb./gal. (4,6-dinitro-*o*-*sec*-butylphenol)	0,6,12

Greenhouse Pot Study

This study was conducted to determine whether the tolerance of cottonwood to five promising herbicides (as evidenced by nursery screening trials) was a result of physiological resistance of the trees or to physical characteristics of the herbicide in the soil which prevented lethal amounts of herbicide from reaching the cottonwood roots. Also, it was possible that some damage to the roots could be caused by the herbicide which was not reflected in survival and height growth.

On April 21, 10-inch cottonwood cuttings were weighed and planted in 6-inch plastic pots containing methylbromide-fumigated, loam soil.

Five herbicides at two rates were applied preemergence to the soil surface around the cuttings. Each treatment was replicated eight times in a randomized block design. The wettable-powder and liquid formulations were mixed with water and applied evenly to the soil surface with a pipette, while the granular material was

sprinkled by hand. The treatments used in this study were as follows:

Chemical	*Rate Lb./A.*
Control	
Dichlobenil 4-G	2,4
Simazine 80W	2,4
Trifluralin 4 lb./gal.	1,2
Diphenamid 80W	2,4
Diuron 80W	1,2

Chemical rates were calculated on a surface area basis.

Cuttings were harvested on July 7 and the length of the longest shoot of each cutting was measured. The soil was carefully washed from the roots, and roots and shoots were separated for fresh and dry weight determination. The data were analyzed by analysis of covariance using the original green weight of the cuttings as the independent variable. Measurements taken from treatments which caused considerable mortality were not analyzed. In the treatments that were analyzed, two trees died and missing data were calculated for these measurements.

Postemergence Herbicides

The tolerance of cottonwood to foliage sprays of dalapon (2, 2-dichloropropionic acid), TCA (trichloroacetic acid, Na salt), and DSMA (disodium methane arsenate) at varying rates was studied on potted cuttings in the nursery. Twelve-inch cuttings were planted in pots of nursery soil in mid-March and treated May 29. Each of these herbicides was applied at three rates and 10 replications in a completely random design, with 10 plants serving as a control. Pots receiving a given treatment were arranged inside a 5×20 feet area and sprayed as though an overall spray were being applied to the entire 100 sq. ft. area. All sprays were applied at a volume of 160 gal./A. and 0.2% x-77 surfactant was added to each spray solution. Survival and height measurements were made in October, 1964.

RESULTS

Preemergence Herbicides

Results from the screening studies indicated that simazine, EPTC, norea, trifluralin (incorporated and unincorporated), dich-

lobenil 50W and 4-G, diuron 28 per cent, and 80W, chloroxuron, diphenamid, sindone and DNBP were not injurious to cottonwood during the first growing season, Tables 1 and 2. The second year measurements of plots treated with simazine, EPTC, norea,

TABLE 1. THE AVERAGE SURVIVAL AND AVERAGE HEIGHT GROWTH OF COTTONWOOD TREES IN THE 1964 SCREENING STUDY[1]

Treatment		Average survival	Average height growth—1964	Average height growth —1965
Chemical	Rate			
	Lb./A.	*Pct.*	*Ft.*	*Ft.*
Atrazine	0	90a	4.54	8.15
	3	88a	3.68	6.62
	6	30b	------	------
	12	13c	------	------
Chloroxuron	0	93	4.01	7.72
	1	95	3.69	6.97
	2	85	4.18	6.92
	4	65	3.91	7.12
Dichlobenil	0	68	4.17	7.42
	4	90	3.84	7.04
	8	90	4.16	6.74
	16	80	4.24	6.97
Diuron	0	85	4.58	8.54
	1	88	4.65	8.22
	2	78	4.75	8.20
	4	88	4.75	8.10
EPTC	0	85	3.80	6.85
	4	88	4.11	7.39
	8	93	4.00	6.99
	12	80	4.44	7.86
Fenac	0	85a	4.39	7.93
	4	73a	4.31	8.04
	8	50b	3.94	7.40
	16	33c	------	------
Norea	0	98	4.41	8.04
	1	85	4.83	8.56
	2	90	4.97	8.31
	4	85	4.33	8.08
Picloram	0	73a	3.46	8.85
	1	5b	------	------
	2	0b	------	------
	4	3b	------	------
Simazine	0	90	3.91	6.47
	3	85	3.81	6.59
	6	88	3.80	6.09
	12	83	3.66	6.20
Trifluralin	0	93	4.15	7.38
	¾	90	4.02	7.42
	1½	88	3.98	6.81
	3	98	4.12	7.32

[1] Averages followed by same letter are not significantly different at 5 per cent level *(11)*. Columns of numbers without letter designations indicate non-significance between treatments.

TABLE 2. THE AVERAGE SURVIVAL AND AVERAGE HEIGHT GROWTH OF COTTONWOOD TREES IN THE 1965 HERBICIDE SCREENING STUDY[1]

Treatment		Average survival	Average height growth
Chemical	Rate		
	Lb./A.	*Pct.*	*Ft.*
Sindone	0	70	8.80
	6	78	7.97
	12	78	8.63
Daxtron	0	75a	9.02
	2	23b	------
	4	15b	------
Dichlobenil	0	80	8.20
	8	58	8.54
	16	53	9.56
Diphenamid	0	70	7.84b
	8	68	9.08a
	16	45	8.97a
Diuron	0	60	8.27
	2	70	8.95
	4	65	8.35
DNBP	0	60	9.14
	6	70	8.62
	12	78	9.90
Trifluralin (unincorporated)	0	73	8.79
	2	60	9.21
	4	43	9.28
Trifluralin (incorporated)	0	70	8.10
	2	73	8.17
	4	60	7.88

[1] Averages followed by same letter are not significantly different at 5 per cent level *(11)*. Columns of numbers without letter designations indicate non-significance between treatments.

trifluralin, dichlobenil, diuron, and chloroxuron still revealed no injury from treatment, Table 1. The substituted pyridines, picloram and daxtron, caused heavy mortality, Tables 1 and 2. Atrazine did not injure the trees at 3 pounds per acre but caused stunting and heavy mortality at 6 and 12 pounds per acre, Table 1. Fenac did not injure the trees at 4 pounds per acre but was quite injurious at the 16 pounds per acre rates, Table 1.

Greenhouse Pot Study

Several chemicals which caused no injury to cottonwood in the nursery were quite toxic to potted cuttings. Simazine at 2 and 4 pounds per acre, diphenamid at 4 pounds per acre, and diuron at 2 pounds per acre greatly reduced survival of the cuttings, Table 3. Three weeks after treatment, symptoms of toxicity became evident on trees which had been treated with simazine at both rates and the high rates of diphenamid and diuron. The toxicity

symptoms for these herbicides consisted of leaf cupping and black lesions on the leaves. The other treatments had no effect on survival, Table 3.

Treatments that did not affect survival, had no significant effect on height growth, dry weight of shoots, and green and dry weight of roots. The measurements obtained from the pot study are summarized in Table 4.

TABLE 3. THE EFFECTS OF PREEMERGENCE CHEMICAL APPLICATIONS ON THE SURVIVAL OF POTTED COTTONWOOD CUTTINGS IN THE GREENHOUSE

Treatment		Survival[1]
	Lb./A.	*Pct.*
Check		100
Dichlobenil 4-G	2	100
	4	88
Simazine 80W	2	40
	4	0
Trifluralin 4 lb./gal.	1	100
	2	100
Diphenamid 80W	2	88
	4	13
Diuron 80W	1	100
	2	25

[1] Survival was not analyzed since differences were quite pronounced.

TABLE 4. THE EFFECTS OF CHEMICAL TREATMENT ON THE AVERAGE HEIGHT AND THE GREEN AND DRY WEIGHT OF SHOOTS AND ROOTS OF POTTED COTTONWOOD IN THE GREENHOUSE[1], [2]

Treatment		Adjusted average height	Adjusted weight of shoots		Adjusted weight of roots	
Chemical	Rate		Green	Dry	Green	Dry
	Lb./A.	*cm.*	*g.*	*g.*	*g.*	*g.*
Check		18.5a	8.2a	2.5a	6.8a	.78a
Dichlobenil	2	17.8a	8.6a	2.6a	6.3a	.58a
	4	13.3a	7.5b	2.2a	5.0a	.36a
Trifluralin	1	18.7a	7.5a	2.2a	6.7a	.54a
	2	21.3a	8.1a	2.2a	6.7a	.55a
Diphenamid	2	14.0a	8.5a	2.1a	7.9a	.71a
Diuron	1	17.0a	8.2a	2.3a	7.5a	.69a

[1] Averages followed by same letter are not significant at 5 per cent level *(11)*. Columns having no letter designations indicate non-significance between treatments.

[2] All averages adjusted for starting fresh weight of cutting.

Postemergence Herbicides

Foliage aprays of dalapon, TCA and DSMA appeared to be highly detrimental to young cottonwood. Survival was not significantly reduced but bud and twig kill greatly reduced height

TABLE 5. THE EFFECT OF DALAPON, DSMA, AND TCA ON THE SURVIVAL AND AVERAGE FIRST YEAR HEIGHT GROWTH OF COTTONWOOD WHEN APPLIED POSTMERGENCE

Treatment		Survival[1]	Average height growth
	Lb./A.	*Pct.*	*Ft.*
Check		100	2.52
Dalapon	5	80	1.43*
	10	90	1.57*
	20	100	1.43*
DSMA	4	70	0.82*
	8	80	1.09*
	16	60	0.87*
TCA	50	70	1.45*
	100	90	0.82*
	150	90	1.02*

[1] No significant difference due to treatment.
* Indicates a significant difference when compared to check.

growth, Table 5. Dalapon appeared to be the least damaging and DSMA the most damaging of the materials tested.

DISCUSSION

Preemergence Herbicides and Greenhouse Pot Study

Simazine and atrazine belong to the *s*-triazine family of herbicides and while the two herbicides are closely related, they produced different effects on cottonwood in the nursery. The fact that simazine was not injurious while atrazine was quite toxic probably is a result of solubility differences. The solubility of simazine is 5 p.p.m. while that of atrazine is 70 p.p.m. *(3)*. Atrazine has been shown to leach more rapidly than simazine in soil columns *(24)*. Simazine was highly injurous to cottonwood cuttings in the greenhouse pot study when the tree roots and the herbicide were confined to the small volume of soil in the pots. In the field, simazine did not leach into the root zone of the cottonwood in sufficient quantities to cause injury. Simazine has been used for weed control around various woody species *(8,18)* and it appears very promising for use in cottonwood plantations.

Diuron, norea and chloroxuron are substituted urea compounds, and appear quite promising for weed control in cottonwood plantations. Since diuron is the most widely used of the three herbicides, the discussion will be centered around this compound. Diuron has a solubility of 42 p.p.m. *(18)* and is not readily leached

more than 4 inches below the surface of the soil *(27)*. The resistance to diuron shown by cottonwood in the nursery probably was a result of slow leaching of the compound and not to detoxification or other physiological resistance of the cuttings. Evidence for this conclusion may be drawn from the fact that diuron injured cottonwood cuttings when brought into close proximity with the roots in the greenhouse pot study. Diuron has been used successfully for weed control around several woody plants *(13,25)*. It appears that diuron might be used at a rate as high as 4 pounds per acre wtihout injury to cottonwood. Small field trials should be established with this chemical before it is used extensively since several soil factors have been reported to affect the toxicity.

Dichlobenil is a relatively new compound that has produced excellent results as a herbicide against a broad spectrum of annual and perennial, broadleaved and grassy weeds *(4)*. The compound has a solubility of 19 p.p.m. *(3)* and is very toxic to germinating seed. Dichlobenil is extremely volatile and should be incorporated into the soil or used in the granular form for maximum effectiveness. Cottonwood appears to be very tolerant of dichlobenil since application up to 16 pounds per acre in the nursery did not cause injury. The tolerance is further supported by the fact that dichlobenil did not cause injury to the potted cuttings. Other workers have used dichlobenil successfully for weed control in planted woody ornamental and nursery stock *(1,4)* and the material appears quite promising for use in cottonwood plantations.

Diphenamid is a non-volatile herbicide recommended for use in ornamentals as well as several vegetable and field crops *(26)*. Ahens *(1)* reported that diphenamid did not cause injury to several ornamental species. The herbicide was injurious to cottonwood in the greenhouse pot study indicating that the resistance of cottonwood in the field studies was a result of a failure of the material to reach cottonwood roots in toxic quantities. Diphenamid may prove useful in cottonwood plantations if the weed spectrum is susceptible to the compound.

Trifluralin is a new herbicide which has been found to control a wide spectrum of grasses and some broadleafed weeds. The compound has a solubility of less than 1 p.p.m. and is quite volatile *(5)*. For best results, the material should be incorporated into the soil after application *(5)*. The lack of injury to cottonwood in the greenhouse pot study was possibly a result of chemical loss by volatilization since no effort was made to incorporate the triflura-

lin. Even though trifluralin does not appear injurious to cottonwood, its usefulness is limited by the incorporation requirement.

Sindone was not toxic to cottonwood at the rates tested but its usefulness in cottonwood plantations cannot be determined until more information is available concerning the effectiveness of the compound as a herbicide.

The remaining chemicals screened do not appear promising for weed control in cottonwood planting. Atrazine, fenac, picloram and daxtron caused injury to the cuttings. EPTC though non-injurious to cottonwood would not be very promising because of the incorporation requirement for effectiveness *(6)*. Davis *(9)* states that DNBP is not promising for weed control in cotton because of its high mamalian toxicity, low degree of selectivity, short period of effectiveness, and erratic behavior under varying climatic and edaphic conditions. These same reasons would also make this compound a poor choice for weed control in cottonwood plantations.

Postemergence Herbicides

Twig and bud damage caused by foliage sprays of dalapon, TCA, and DSMA rule out their use as nondirected postemergence sprays in cottonwood plantations. They could probably be applied postemergence if the cottonwood plants were shielded at the time of spraying. Dalapon appears to be the most promising since it is effective against Johnsongrass (*Sorghum halepense*), *(14)* and was the least injurious of the grass-killers to cottonwood.

IMPLICATIONS

Concrete recommendations for weed control in cottonwood plantations cannot be made at the present time. The following comments are only general implications and suggestions. Specific recommendations will have to await extensive field trials under widespread conditions.

The problem of weed control in cottonwood plantations should be divided into three categories: (1) control of broadleaf weeds and annual grasses, (2) control of woody vines and trees, and (3) control of johnsongrass.

When the principal competition is from annual weeds and grasses, dichlobenil at 4 to 8 pounds per acre, simazine at 6 to 10 pounds per acre, or diuron at 2 to 4 pounds per acre should

do a good job. These chemicals are most effective when applied preemergence to the weeds. In a forestry operation considerable weed germination may occur between the last site preparation in the fall and the first application of herbicide in April or May. In agronomic practice, the soil is normally well tilled just prior to planting and applying herbicide. It is frequently impractical to till at the time cottonwood is planted and the application of herbicide at planting time subjects the chemical to much leaching before the bulk of the weeds begin their growth. When the first application of herbicide is made to cottonwood plantations in April, May or even later in wet years, the ground is probably already covered with many tiny weeds. Many of these may not be controlled by the preemergence herbicides, dichlobenil, simazine or diuron. This problem can be overcome by (1) using a good surfactant in the spray solution which will increase the contact injury to the emerged weeds or (2) incorporating a small amount of postemergence herbicide in the spray mixture. Of course, the granular dichlobenil is not suited for use with surfactants or combinations.

Paraquat, amitrole, DSMA, MSMA or 2,4-D at low rates, e.g. 1 to 2 pounds per acre could be incorporated with simazine or diuron and applied as a directed spray. However, information on compatibility of the desired chemicals should be obtained before mixing. Incompatible herbicides should be sprayed from separate tanks. One application of herbicide probably will not give season-long weed control. Two applications of diuron at 2 pounds per acre or simazine at 6 pounds per acre would probably give effective weed control. When herbicides are applied after the cottonwood has sprouted, the cuttings should be shielded from the herbicide.

It is felt at the present time that band applications of an herbicide should be made instead of broadcast applications. The weeds between sprayed bands could then be eliminated by disking. The spacing between the rows in the plantation should be wide enough so that one pass with the tractor would disk the necessary area. The herbicide should be applied in a continuous band over the row at what ever width necessary to overlap the disked middles. The tractor might be rigged to apply the herbicide and disk the middles at the same time. All herbicide rates should be calculated on a "sprayed acre" basis. Therefore, if spacing were 10 by 10 feet and a 2-foot band were sprayed, application of diuron at 4

pounds per acre would require only 0.8 pound of diuron per acre of plantation. The cost of chemical would be almost negligible.

The named system should (1) eliminate hoeing, (2) eliminate cross-disking, and (3) possibly reduce the number of diskings since weeds would not be so closely associated with the cuttings.

The problem of controlling perennial grasses and woody plants is more difficult than controlling annuals. If possible, perennials should be dealt with prior to plantation establishment. Mist-blower applications of 2,4-D, 2,4,5-T, picloram, or a combination should be effective on woody vines and trees too small to deaden with a tree injector, but the residual effect of picloram on cottonwood would have to be determined.

Johnsongrass should be treated the year before planting. Once the plantation is established, johnsongrass could be safely controlled with DSMA, MSMA, or dalapon with surfactant provided the trees were shielded at the time of herbicide application.

SUMMARY

Populus deltoides Bartr. was found to tolerate preemergence applications of the following chemical treatments on the sandy loam soil of the Auburn Forest Nursery: trifluralin up to 4 pounds per acre; dichlobenil up to 16 pounds per acre; diuron up to 4 pounds per acre; simazine up to 12 pounds per acre; chloroxuron up to 4 pounds per acre; EPTC up to 12 pounds per acre; diphenamid up to 16 pounds per acre; DNBP up to 12 pounds per acre; norea up to 4 pounds per acre; and sindone up to 12 pounds per acre.

The above rates were the highest tested during this study. Atrazine was not injurious at 3 pounds per acre but was highly toxic at 6 and 12 pounds per acre. Fenac was not injurious to cottonwood at 4 pounds per acre but was toxic at the 8 and 16 pounds per acre rates. As little as 1 pound per acre of picloram and 2 pounds per acre of daxtron caused severe mortality. Of the herbicides screened, simazine, diuron, diphenamid and dichlobenil are probably the most promising herbicides for use in cottonwood plantings because of the broad spectrum of weeds controlled by each of these herbicides.

In the greenhouse pot study, trifluralin and dichlobenil did not injure the cuttings.

Dalapon, TCA and DSMA were toxic when applied to the foliage of cottonwood. Dalapon caused the least injury compared to the other two postemergence chemicals.

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