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Bio-efficacy of agrochemicals against bacterial canker (*Xanthomonas citri* pv. *citri*) in citrus

HN Prajapati and AH Barad

Abstract
Citrus is the most extensively produced tree fruit crop in the world. *Citrus* sp. are susceptible to a number of destructive diseases that are continuously emerging and which can severely limit production or totally decimate the industries of the country. Among these citrus canker is one of the most important biotic constraints in the country. The present study was undertaken to find the best and most economical agrochemical in managing this disease. The study of two year trial suggested that four aerial sprays of streptomycin sulphate 90% + tetracycline hydrochloride 10% and copper oxychloride 50 WP or Bordeaux mixture 1% (Tank mixed) started first at initiation of disease and subsequent three sprays at 20 days interval for effective and economical management of bacterial canker in citrus with quality fruit yield.

Keywords: Agrochemicals, bacterial canker, *Xanthomonas citri* pv. *citri*, citrus

Introduction

- Citrus is the second largest industry in India with respect to an area 10.64 lakh ha and third largest with respect to production 99.45 lakh MT. Among the different states, Kinnow mandarin is an important fruit crop of Punjab cultivated in an area of 49, 244 ha by producing 10, 15, 628 tons/annum fresh fruit.
- The average citrus production in India is quite low (7-8 tons/ha) as compared to other countries (20-25 tons/ha) due to the involvement of number of biotic and abiotic factors responsible for causing "citrus decline" syndrome. Among the various biotic factors, citrus canker disease has played a significant role in declining the citrus grove in India.
- It causes necrotic lesions on fruits, leaves and twigs. Lesions first appear dark green and later become thickened brown and corky. Severe attack causes heavy defoliation, twigs die-back and premature fruit drop.
- The causal agent of citrus canker was earlier identified as bacterium *Pseudomonas citri* by Hasse (1915) [4] but later Dye *et al* (1980) [5] proposed the name *Xanthomonas campestris* pv. *citri* which was again reclassified as *Xanthomonas axonopodis* pv. *citri* (Hasse) Vaut. by Vauterin *et al* (1995) [6].

Material and Method

Method of application

The existing citrus orchard was selected at Horticulture farm, AAU campus field for the experiment. The required plants having equal growth, age and canopy were selected by adopting completely randomized design with three replications. The recommended practices except disease control was followed during experiment. The first spray was made at initiation of disease as per recommended check. Subsequent three sprays were made after 20 days of first spray. The data on development of canker lesion on 50 randomly selected leaves and fruits were recorded after 20 days of second and fourth spray. The data of disease intensity on twigs was recorded by randomly selected 20 twigs per tree. The area of canker lesions were recorded from 45 cm size of each selected twigs. The Disease intensity was recorded by observing canker lesion on leaf, fruit and twigs by using 0-5 grade (Thind and Aulakh, 2007) [9]. Disease Rating on citrus canker was followed as 0- No disease, 1- 1-20% leaf/fruit/twig area covered with canker, 2-21-40% leaf/fruit/twig area covered with canker, 3- 41-60% leaf/fruit/twig area covered with canker, 4- 61-80% leaf/fruit/twig area covered with canker, 5- 80-100% leaf/fruit/twig area covered with canker. Based on these data, yield of fruits per tree was calculated for each treatment.

The data were subjected to ANOVA. The percent disease intensity (PDI) was calculated by using the following formula:

$$PDI = \frac{\text{Sum of numerical rating}}{\text{No. Of leaves observed x Maximum disease scale value (5)}} \times 100$$

Calculation of percent disease intensity (PDI) in leaves

Treatment details:

Treat. No.	Treatment detail	Concentration
T_1	Copper oxychloride 50 WP	0.2%
T_2	Copper hydroxide 53.5 DF	0.2%
T_3	Validamycin 3 L	100 ppm
T_4	Streptomycin sulphate 90% + Tetracycline hydrochloride 10% SP (Streptocycline)	100 ppm
T_5	Streptomycin sulphate 90% + Tetracycline hydrochloride 10% SP (Streptocycline) and Copper oxychloride 50 WP (Tank mixed)	100 ppm and 0.2%
T_6	Streptomycin sulphate 90% + Tetracycline hydrochloride 10% SP (Streptocycline) and Copper hydroxide 53.5 DF (Tank mixed)	100 ppm and 0.2%
T_7	Bordeaux mixture (Recommended Check)	1%
T_8	Control (Untreated check)	--

Result and Discussion

On leaves (Table.1)

The data on disease intensity on leaves revealed that all the treatments recorded significantly minimum area of lesion as compared to control. There were no significant differences in disease intensity in various treatments before application and the result was found non-significant.

The data of 20 days after second spray in first year revealed that minimum canker intensity was found in treatment T_5 i.e. Streptomycin sulphate 90% + Tetracycline hydrochloride 10% and Copper oxychloride 50 WP (9.70) which was at par with treatment T_7 i.e. Bordeaux mixture (1%) (11.10 PDI). The data on pooled over period recorded that minimum disease intensity was recorded in treatment T_5 i.e. Streptomycin sulphate 90% + Tetracycline hydrochloride 10% and Copper oxychloride 50 WP (12.41%). The next best treatment in order of merit was treatment T_7 i.e. Bordeaux mixture (1%). During 2018-19, the data of 20 days after second spray revealed that the minimum disease intensity was recorded in treatment T_5 i.e. Streptomycin sulphate 90% + Tetracycline hydrochloride 10% and Copper oxychloride 50 WP (18.56). The data of pooled over period of disease intensity on leaf was found that the least disease intensity by treatment T_5. The next best treatment in order of merit was treatment T_7 i.e. Bordeaux mixture (1%) (24.32 PDI) which was at par with treatment T_6.

The data on pooled over period, application and year suggested that the least disease intensity was found in treatment T_5 i.e. Streptomycin sulphate 90% + Tetracycline hydrochloride 10% and Copper oxychloride 50 WP (16.73%) which was at par with treatment T_7 i.e. Bordeaux mixture (1%) (18.75 PDI).

On fruits (Table-2)

The data on disease intensity on fruit revealed that all the treatments recorded significantly minimum canker as compared to control. There were no significant differences in disease intensity in various treatments before application and the result was found non-significant.

The data of 20 days after second spray revealed that minimum canker intensity was found in treatment T_5 i.e. Streptomycin sulphate 90% + Tetracycline hydrochloride 10% and Copper oxychloride 50 WP (10.44%) which was at par with treatment T_7 i.e. Bordeaux mixture (1%) (10.93 PDI). The data on pooled over period found that minimum disease intensity was found in treatment T_5 i.e. Streptomycin sulphate 90% + Tetracycline hydrochloride 10% and Copper oxychloride 50 WP (11.74%) which was at par with recommended check i.e. treatment T_7 (Bordeaux mixture). The result of second year on disease intenity on fruit revealed that the minimum disease intensity was found in treatment T_5 i.e. Streptomycin sulphate 90% + Tetracycline hydrochloride 10% and Copper oxychloride 50 WP (17.41%). The next best treatment in order to minimum disease intensity was treatment T_7 i.e. Bordeaux mixture (1%) (16.95 PDI) which was at par with treatment T_6 and T_4. The data on pooled over period found that minimum disease intensity was found in treatment T_5 i.e. Streptomycin sulphate 90% + Tetracycline hydrochloride 10% and Copper oxychloride 50 WP (17.00%).

The data on pooled over period, application and year suggested that the least disease intensity was found in treatment T_5 i.e. Streptomycin sulphate 90% + Tetracycline hydrochloride 10% and Copper oxychloride 50 WP (16.73%) which was at par with treatment T_7 i.e. Bordeaux mixture (1%) (18.75 PDI).

On twigs (Table-3)

The data on disease intensity on twigs revealed that all the treatments recorded significantly minimum canker as compared to control. There were no significant differences in disease intensity in various treatments before application and the result was found non-significant.

The data of 20 days after second spray revealed that minimum canker intensity was found in treatment T_5 i.e. Streptomycin sulphate 90% + Tetracycline hydrochloride 10% and Copper oxychloride 50 WP (9.13%) The next best treatment in order of merit was treatment T_7 i.e. Bordeaux mixture (10.62) which was at par with treatment T_6 i.e. Streptomycin sulphate 90% + Tetracycline hydrochloride 10% and Copper hydroxide 50 WP (11.34 PDI). The data on pooled over period found that minimum disease intensity was found in treatment T_5 i.e. Streptomycin sulphate 90% + Tetracycline hydrochloride 10% and Copper oxychloride 50 WP (10.22%) which was at par with recommended check i.e. treatment T_7 Bordeaux mixture and treatment T_6 i.e. Streptomycin sulphate 90% + Tetracycline hydrochloride 10% and Copper

hydroxide 50 WP .

The data of 20 days after second spray during 2018-19 revealed that minimum canker intensity was found in treatment T_5 i.e. Streptomycin sulphate 90% + Tetracycline hydrochloride 10% and Copper oxychloride 50 WP (8.15%) The next best treatment in order of merit was treatment T_7 i.e. Bordeaux mixture (10.62) which was at par with treatment T_6 i.e. Streptomycin sulphate 90% + Tetracycline hydrochloride 10% and Copper hydroxide 50 WP (10.28 PDI) which was at par with treatment T_6. The data on pooled over period found that minimum disease intensity was found in treatment T_5 i.e. Streptomycin sulphate 90% + Tetracycline hydrochloride 10% and Copper oxychloride 50 WP (9.90%) The next best treatment in order of merit was i.e. treatment T_7 Bordeaux mixture which was at par with treatment T_6 i.e. Streptomycin sulphate 90% + Tetracycline hydrochloride 10% and Copper hydroxide 50 WP.

The data on pooled over period, application and year suggested that the least disease intensity was found in treatment T_5 i.e. Streptomycin sulphate 90% + Tetracycline hydrochloride 10% and Copper oxychloride 50 WP (16.73%) which was at par with treatment T_7 i.e. Bordeaux mixture (1%) (10.06 PDI).

Fruit yield (Table-4)

The data of 2017-18 of fruit yield revealed that maximum citrus fruit yield was found in treatment T_5 i.e Streptomycin sulphate 90% + Tetracycline hydrochloride 10% and Copper oxychloride 50 WP (47.53 Kg/tree) which was at par with treatment T_7 i.e. Bordeaux mixture (Recommended Check) with 42.81 kg/tree. The data of 2018-19 on citrus fruit yield revealed that maximum citrus fruit yield was found in treatment T_5 i.e. Streptomycin sulphate 90% + Tetracycline hydrochloride 10% and Copper oxychloride 50 WP (43.60 Kg/tree) which was at par with treatment T_7 i.e. Bordeaux mixture (Recommended Check) with 39.40 Kg/tree.The pooled data of 2017-18 and 2018-19 on citrus fruit yield revealed that maximum citrus fruit yield was found in treatment T_5 i.e. Streptomycin sulphate 90% + Tetracycline hydrochloride 10% and Copper oxychloride 50 WP (45.53 Kg/tree) which was at par with treatment T_7 i.e. Bordeaux mixture (Recommended Check) with 41.20 Kg/tree.

Ravikumar *et al* (2002) [7] reported that pruning of infected parts along with one spray of Copper oxychloride followed by four sprays of Streptocyclinee (100 ppm) + Copper oxychloride (0.3%) was found promising in reducing the bacterial canker of acid lime. Gopal *et al* (2004) suggested that pruning of dried and cankerous twigs with immediate spray of Copper oxychloride (0.3%) followed by two sprays of Streptocyclinee (100 ppm) + Copper oxychloride (0.3%) at monthly interval starting from June effectively reduced the acid lime canker on twig, foliage and fruit with high yield of cankerless, good marketable fruits, which benefited the farmer with cost benefit ratio of 1:1.59 Sprays of Bactrinashak and Streptocyclinee have also been proved most effective in reducing the intensity of citrus canker in Kinnow mandarin (Thind and Aulakh 2007) [9]. Kale *et al.* (1994) [1] suggested that for effective management of canker, spraying of streptocycline + Copper oxychloride (0.1%) should preferably be done at 7 days or 15 days interval. Patel and Desai (1970) [2] reported that pruning of affected twigs every year during Nov-Dec and 3 to 4 sprays of Bordeaux mixture (1%) in a year could reduce the disease. Two prunings alongwith 4 sprays of 5000 ppm copper oxychloride or 1% Bordeaux mixture is reported to be effective against the disease (Kishun and Chand, 1987) [3]

Table 1: Evaluation of different agrochemicals against citrus canker on leaves

Treatment	Disease Intensity on leaves (%)								Pooled over period, application and Years
	2017-2018				2018-2019				
	Before Spray	20 DASS	20 DAFS	Pooled	Before Spray	20 DASS	20 DAFS	Pooled	
T_1	32.63a (29.07)	28.52b (22.80)	25.40bc (18.40)	26.96b (20.55)	36.28a (35.01)	34.93b (32.78)	29.29bcd (23.93)	32.11b (28.25)	29.53bc (24.29)
T_2	33.19a (29.97)	28.96b (23.44)	26.47b (19.87)	27.72b (21.64)	36.87a (36.00)	33.31bcd (30.16)	30.14bc (25.21)	31.72b (27.64)	29.72bc (24.58)
T_3	32.43a (28.76)	29.44b (24.16)	27.60b (21.46)	28.52b (22.80)	36.12a (34.75)	34.00bc (31.27)	30.54b (25.82)	32.27b (28.51)	30.39b (25.59)
T_4	32.84a (29.41)	28.51b (22.78)	23.64cd (16.08)	26.08bc (19.33)	36.51a (35.40)	32.62cde (29.06)	26.14e (19.41)	29.38c (24.07)	27.73bcd (21.65)
T_5	33.54a (30.53)	23.12c (15.42)	18.15e (9.70)	20.63e (12.41)	37.19a (36.54)	29.78f (24.67)	25.52e (18.56)	27.65d (21.54)	24.14e (16.73)
T_6	33.38a (30.27)	25.25c (18.20)	22.57d (14.73)	23.91cd (16.43)	37.03a (36.24)	31.37def (27.10)	28.72cd (23.09)	30.05c (25.08)	26.97cd (20.57)
T_7	32.95a (29.58)	24.06c (16.62)	19.46e (11.10)	21.76de (13.74)	36.62a (35.58)	31.09ef (26.67)	28.09d (22.17)	29.55c (24.32)	25.66de (18.75)
T_8	33.50a (30.46)	35.83a (34.27)	39.28a (40.08)	37.55a (37.14)	37.41a (36.91)	39.29a (40.10)	42.05a (44.86)	40.89a (42.85)	39.22a (39.98)
S. Em.± T	0.79	0.78	0.83	0.80	0.74	0.61	0.51	0.40	0.87
Period P	--	--	--	0.28	--	--	--	0.20	0.17
Spray S	--	--	--	--	--	--	--	--	0.17
T x P	--	--	--	1.37	--	--	--	0.56	0.49
T x S	--	--	--	--	--	--	--	--	0.49
P x S	--	--	--	--	--	--	--	--	0.26
C.D. at 5% T	NS	2.33	2.49	2.32	NS	1.85	1.53	1.15	2.91
Period P	--	--	--	--	--	--	--	0.57	0.49
Spray S	--	--	--	--	--	--	--	--	0.49
T x P	--	--	--	4.56	--	--	--	1.63	0.00

T x S	--	--	--	--	--	--	--	--	0.00
P x S	--	--	--	--	--	--	--	--	NS
TxPxS									NS
C. V.%	4.11	4.81	5.69	5.23	3.52	3.22	2.94	3.10	4.13
Notes	:DASS: Days After Second Spray; DAFS: Days After Fourth Spray NS: Non significant :Figures in parentheses are retransformed values; those outside arc sine transformed values Treatment means with the letter(s) in common are not significant by DNMRT at 5% level of significance								

Table 2: Evaluation of different agrochemicals against citrus canker on fruits

Treatment	Disease Intensity on fruits (%)								Pooled over period, application and Years
	2017-2018				2018-2019				
	Before Spray	20 DASS	20 DAFS	Pooled	Before Spray	20 DASS	20 DAFS	Pooled	
T_1	29.79a (24.68)	27.49bc (21.31)	26.09bc (19.34)	26.79b (20.32)	32.17a (28.35)	29.55bc (24.32)	26.12bc (19.38)	27.83bcd (21.79)	27.31b (21.05)
T_2	29.87a (24.80)	28.31b (22.49)	26.10bc (19.35)	27.21b (20.91)	31.82a (27.80)	30.33b (25.50)	26.10bc (19.35)	28.21bc (22.34)	27.71b (21.62)
T_3	29.59a (24.38)	28.75b (23.14)	27.87b (21.85)	28.31b (22.49)	31.54a (27.36)	28.76bc (23.15)	27.86b (21.84)	28.31b (22.49)	28.31b (22.49)
T_4	28.38a (22.59)	28.84b (23.27)	25.09c (17.98)	26.97b (20.57)	30.39a (25.59)	28.80bc (23.21)	25.10cd (17.99)	26.94cde (20.53)	26.95b (20.54)
T_5	29.46a (24.19)	21.23e (13.11)	18.85e (10.44)	20.04d (11.74)	31.43a (27.19)	26.39d (19.76)	22.31e (14.41)	24.35f (17.00)	22.19d (14.26)
T_6	30.09a (25.14)	24.82cd (17.62)	22.20d (14.28)	23.51c (15.91)	32.03a (28.13)	28.65bc (22.99)	24.66cd (17.41)	26.66de (20.13)	25.08c (18.02)
T_7	28.73a (23.11)	22.35de (14.46)	19.31e (10.93)	20.83d (12.64)	30.72a (26.10)	27.59cd (21.45)	24.31d (16.95)	25.95e (19.15)	23.39cd (15.76)
T_8	29.35a (24.02)	32.15a (28.32)	36.19a (34.86)	34.17a (31.55)	31.31a (27.01)	33.41a (30.32)	35.05a (32.98)	34.23a (31.64)	34.19a (31.58)
S. Em. ± T	0.61	0.85	0.70	0.78	0.56	0.66	0.53	0.41	1.03
Period P	--	--	--	0.28	--	--	--	0.20	0.17
Spray S	--	--			--	--			0.42
T x P	--	--	--	1.21	--	--	--	0.59	0.48
T x S	--	--	--	--	--	--	--	--	0.48
P x S	--	--	--	--	--	--	--	--	0.24
C.D. at 5% T	NS	2.54	2.10	2.24	NS	1.94	1.58	1.20	3.46
P	--	--	--	--	--	--	--	0.60	0.48
S	--	--	--	--	--	--	--	--	0.48
T x P	--	--	--	4.050	--	--	--	1.70	0.00
T x S	--	--	--	--	--	--	--	--	0.00
P x S	--	--	--	--	--	--	--	--	0.69
TxPxS	--	--	--	--	--	--	--	--	NS
C. V.%	3.62	5.49	4.82	5.19	3.12	3.83	3.56	3.67	4.46
Notes	: DASS: Days After Second Spray; DAFS: Days After Fourth Spray NS: Non significant :Figures in parentheses are retransformed values; those outside arc sine transformed values Treatment means with the letter(s) in common are not significant by DNMRT at 5% level of significance								

Table 3: Evaluation of different agrochemicals against citrus canker on twigs

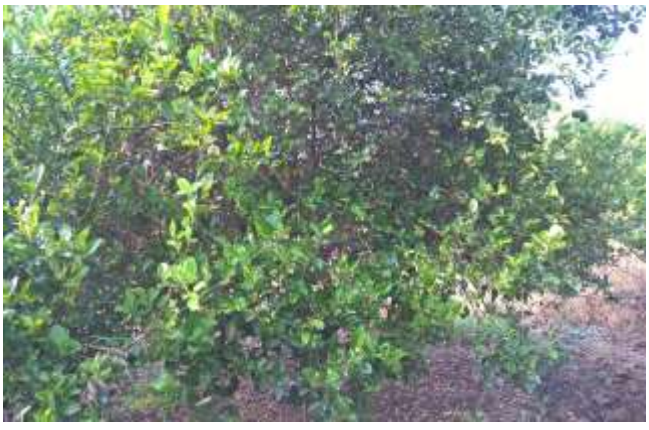
Treatment	Disease Intensity on twigs (%)								Pooled over period, application and years
	2017-2018				2018-2019				
	Before Spray	20 DASS	20 DAFS	Pooled	Before Spray	20 DASS	20 DAFS	Pooled	
T_1	23.89a (16.40)	22.28bc (14.37)	22.36bc (14.47)	22.32bc (14.42)	25.40a (18.40)	23.86c (16.36)	21.55c (13.49)	22.70c (18.49)	22.51c (14.66)
T_2	24.12a (16.70)	23.82b (16.31)	23.00b (15.27)	23.41b (15.79)	25.62a (18.70)	24.61bc (17.34)	22.99b (15.25)	23.80b (16.28)	23.60b (16.03)
T_3	23.01a (15.28)	24.23b (16.84)	23.25b (15.58)	23.74b (16.21)	24.57a (17.29)	25.83b (18.98)	23.24b (15.57)	24.53b (17.24)	24.13b (16.71)
T_4	23.65a (16.09)	21.69c (13.66)	20.74cd (12.54)	21.22cd (13.10)	25.43a (18.44)	21.70d (13.67)	20.45cd (12.21)	21.07d (12.92)	21.14d (13.01)
T_5	23.15a (15.46)	19.69d (11.35)	17.59e (9.13)	18.64e (10.22)	24.69a (17.45)	19.69e (11.35)	16.99f (8.54)	18.34f (9.90)	18.49f (10.06)
T_6	24.00a (16.54)	21.12cd (12.98)	19.68d (11.34)	20.40de (12.15)	25.51a (18.55)	21.11de (12.97)	19.42de (11.05)	20.26de (11.99)	20.33e (12.07)
T_7	23.46a (15.85)	20.61cd (12.39)	19.02de (10.62)	19.82de (11.50)	25.00a (17.86)	20.61de (12.39)	18.70e (10.28)	19.65e (11.31)	19.73e (11.40)
T_8	24.01a (16.56)	30.15a	32.01a	31.08a	25.53a	28.35a	30.28a	29.32a	30.19a

		(25.23)	(28.10)	(26.65)	(18.57)	(22.55)	(25.24)	(23.98)	(25.29)
S. Em.± T	0.69	0.61	0.56	0.59	0.52	0.46	0.43	0.32	0.26
Period P	--	--	--	0.21	--	--	--	0.16	0.13
Spray S	--	--	--	--	--	--	--	--	0.13
T x P	--	--	--	0.62	--	--	--	0.45	0.37
T x S	--	--	--	--	--	--	--	--	0.37
P x S	--	--	--	--	--	--	--	--	0.18
C.D. at 5% T	NS	1.84	1.69	2.06	NS	1.40	1.30	0.92	0.74
P	--	--	--	--	--	--	--	0.46	NS
S	--	--	--	--	--	--	--	--	0.37
T x P	--	--	--	NS	--	--	--	1.30	0.00
T x S	--	--	--	--	--	--	--	--	NS
P x S	--	--	--	--	--	--	--	--	NS
TxPxS	--	--	--	--	--	--	--	--	NS
C. V.%	5.06	4.64	4.40	4.52	3.63	3.49	3.46	3.48	4.03
Notes	: DASS: Days After Second Spray; DAFS: Days After Fourth Spray NS: Non significant :Figures in parentheses are retransformed values; those outside arc sine transformed values Treatment means with the letter(s) in common are not significant by DNMRT at 5% level of significance								

Table 4: Evaluation of different agrochemicals on yield of citrus

Treatment	Treatment detail	Citrus yield Kg/tree		
		2017-2018	2018-2019	Pooled
T_1	Copper oxychloride 50 WP	37.10bcd	34.20cd	35.65de
T_2	Copper hydroxide 53.5 DF	35.26cd	32.93cd	34.10ef
T_3	Validamycin 3% L	32.90d	33.53cd	33.22ef
T_4	Streptomycin sulphate 90% + Tetracycline hydrochloride 10% (Streptocycline)	39.22bc	35.90bc	37.57cd
T_5	Streptomycin sulphate 90% + Tetracycline hydrochloride 10% (Streptocycline) and Copper oxychloride 50 WP (Tank mixed)	47.53a	43.60a	45.57a
T_6	Streptomycin sulphate 90% + Tetracycline hydrochloride 10% (Streptocycline) and Copper hydroxide 53.5 DF (Tank mixed)	41.80ab	36.67bc	39.23bc
T_7	Bordeaux mixture (Recommended Check)	42.81ab	39.40b	41.20b
T_8	Control	32.17d	30.80d	31.49f
S. Em.± T		1.74	1.20	1.08
Period P		--	--	0.53
T x P		--	--	1.50
C.D. at 5% T		5.21	3.62	3.11
P		--	--	--
T x P		--	--	NS
C. V.%		7.89	5.82	6.95

Treatment T_5



Untreated Control

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