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Demonstrations of Pendimethalin for Control of *Phalaris minor* in Wheat Crop

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ABSTRACT

The present study was carried out in Barnala district of Punjab during Rabi-2015-16. Front line demonstrations on pendimethalin for control of *Phalaris minor* in wheat crop were carried out in different farmers' fields. On comparison with farmers' practices, it was recorded that the application of pendimethalin @ 1000 ml/acre resulted less Phalaris minor density, weed dry weight and maximum WCE as compared to other farmers practices viz. Clodinafop @160 to 300 g/acre, Pinoxaden 400 to 500 ml/acre, Sulfosulfuron @ 13 g/acre, Mesosulfuron + Iodosulfuron (Atlantis) @160 to 200 g/acre and Sulfosulfuron + Metsulfuron (Total) @ 16g/acre. Application of pendimethalin @ 1000 ml/acre also result more plant height, effective tillers, grain yield, net return and B: C ratio as compared other farmers practices. The application of pendimethalin @ 1000 ml/acre in wheat crop had no residual effect on growth and yield of succeeding crop (fodder maize, sesbania, rice, moong and cotton) as responded by 85 farmers. Lack of knowledge about pendimethalin for weed control in wheat (18.8%), fear of low benefit: cost ratio (16.5%), busy schedule at the time of sowing (14.1%), lack of guidance for pendimethalin application (11.8%), fear of ineffectiveness of pendimethalin (10.6%) were the major reasons towards non-adoption. Publicising the details in respect to dose, time and method of application and intensive training programme on herbicide use in farmers' field were felt as some crucial steps for increasing the adoption level.

Key words: Wheat, Phalaris Minor, Pendimethalin, Weed Control, Economics

INTRODUCTION

India is the world's second largest producer of wheat. The crop productivity (in 2013) in India is low for wheat (3.15 t ha-1) as compared to global averages of 3.26 t ha-1 (FAO, 2016), and needs to be increased to meet the food grain requirements of the growing population. Among several factors responsible for low productivity, weeds were a major biological constraint that limits the production of wheat by 10-60 per cent (Yaduraju *et al.,* 2015). The predominant weeds associated with conventional till wheat are *P. minor, Poa annua L., Polypogon monspeliensis, Avena ludoviciana, Rumex dentatus L., R. spinosus, A. arvensis, Convolvulus arvensis L., Malva parviflora, M. denticulata, Chenopodium album, Vicia sativa, Lathyrus aphaca, Circium arvense (L.)* Scop., *Melilotus alba, Coronopus didymus, Polygonum plebejum,* and *Spergula arvensis* (Chhokar *et. al.,* 2012, Singh *et. al.,* 2015). In irrigated wheat of India, P. minor is highly competitive weed among grassy weeds and can cause drastic yield reduction (25-30 %) under heavy infestation (Yadav and Malik, 2005) and even in less intensity (15 planta/m2) significant decrease (14%) in yield was reported by Kaur *et al.,* 2012. The evolution of resistance in *P. minor* against isoproturon, sulfosulfuron, clodinafop, fenoxaprop and tralkoxydim has made it the single most serious weed species limiting wheat productivity in the north-western plains of India (Malik and Singh, 1993; Chhokar and Malik, 2002; Chhokar and Sharma, 2008). The multiple resistance problems at few locations are so severe that it is causing huge grain yield reductions (Chhokar and Sharma, 2008). However, these multiple resistant populations are sensitive to triazine (metribuzin and terbutryn) and dinitroaniline (pendimethalin) herbicides. Pendimethalin herbicide can be used effectively to control resistant population of *Phalaris minor.* Application of pendimethalin at 2.5 l/ha within two days of sowing provided effective control of *Phalaris minor* in wheat (Kaur *et al.,* 2014). The sulfonylurea herbicides are known for their persistence in soil (Blair and Martin 1988) and thus have soil residual toxicity to some of the sensitive crops (Moyer 1995). The sulfonylurea herbicides applied in wheat caused residual toxicity to

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maize but not to transplanted rice, urd bean, mung bean and cotton (Singh *et al.* 2003, Yadav *et al.,* 2004 and Kaur and Brar, 2014). Pendimethalin (0.5 and 0.75 kg ha-1) applied to isabgol (Plantago ovata Forsk.) in rabi season had no residual effects on succeeding crop of soybean [Glycine max (L.) Merrill], mung bean (Phaseolus radiata L.), cowpea [Vigna unguiculata (L.) Walp.], sorghum [Sorghum bicolor (L.) Moench] and maize (Zea mays L.) which can safely be grown in kharif season in the rotation (Kulmi, 2009). With limited herbicides options available pendimethalin appears to be the best option for management of P. minor in wheat. Keeping these points in view the demonstrations on pendimethalin for control of P. minor in wheat were conducted in different farmers' fields for adoption of this technology.

METHODOLOGY

The present study was carried out in Barnala district of Punjab during Rabi-2015-16. Front line demonstrations on pendimethalin for control of Phalaris minor in wheat crop were carried out in five villages (Dhilwan, Wazide khurd, Jhloor,) of Barnala (Punjab) in order to demonstrate the benefits of this herbicide. As a whole, 85 numbers of FLD were conducted. Beneficiary selection for FLDs was made through discussion and personal contact with farmers on the basis of certain socio-personal characteristics like SES, innovativeness, progressiveness and risk orientation. The farmers adopted Rice -Wheat-Moong (12 farmers), Rice - Wheat- Green manuring (Dhancha) (11 farmers), Rice - Wheat- maize (fodder) (33 farmers), Rice- wheat (26 farmers) and Cotton-wheat (3 farmers) crop rotation during the study year. The area under each demonstration was 1 acre. Application of pendimethalin @ 1000 ml/acre was compared with existing chemical control of *Phalaris minor*. The other weeds in pendimethalin treated plots were also kept under control. Weedy and weed free plots were also maintained for comparison. Out of 85 farmers, thirteen farmers used clodinafop @ 160 to 300 g/acre, sixteen farmers used Atlantis (mesosulfuron + iodosulfuron) @ 160 to 200 g/acre, twenty-five used total (sulfosulfuron + metsulfuron)@ 16 g/acre, eight used axil (pinoxaden) @ 400 to 500 ml/ acre, sixteen used leader (Sulfosulfuron) @ 13 g. Through, farmers meeting and field visit during the cropping period, time to time monitoring of FLD plots were carried out and farmers were advised to carry out operations accordingly. The knapsack sprayer fitted with flat fan nozzle was used for spray with volume of 200 litres per acre. Agronomic cultivation practices like field preparation, fertilizer application, and plant protection measures were done as per PAU, packages and practices. Five random samples of one-meter square area from each demonstration fields were selected for *Phalaris minor* data. Weed density and dry weight were recorded at harvest. The dry weight of weed was calculated on sundry basis. The data on plant height, effective tillers and grain yield of wheat crop was recorded at the time of crop harvest. Weed control efficiency (WCE was calculated by using the formula:

$$WCE = \frac{\text{Weed dry weight in weedy plot-Weed dry weight in treated plot}}{\text{Weed dry weight in weedy plot}} \times 100$$

RESULTS AND DISCUSSION

Weed intensity

The application of pendimethalin @ 1000 ml/acre in different fields of farmers recorded less *Phalaris minor* population as compared to weedy check. The population of Phalaris minor ranges from 1 to 9 per m^2 in farmers fields treated with pendimethalin @ 1000 ml/acre while it ranges from 12 to 38 per m^2 in weedy plots of farmers (fig.1). On comparison with farmers' practices, it was recorded that the application of pendimethalin @ 1000 ml/acre resulted less *Phalaris minor* density as compared to other farmers practices [Clodinafop @160 to 300 g/acre, Pinoxaden 400 to 500 ml/acre, Sulfosulfuron @ 13 g/acre, Mesosulfuron + Iodosulfuron (Atlantis) @160 to 200 g/acre and Sulfosulfuron + Metsulfuron (Total) @ 16g/acre] Table 1. The average *Phalaris minor* population was 3.9 per m^2 in farmers fields treated with pendimethalin @ 1000 ml/acre while 28.1 per m^2 in weedy plots of farmers. In different farmers practices, Clodinafop @160 to 300 g/acre, Pinoxaden 400 to 500 ml/acre, Sulfosulfuron @ 13 g/acre, Mesosulfuron + Iodosulfuron (Atlantis) @160 to 200 g/acre and Sulfosulfuron + Metsulfuron (Total) @ 16g/acre results average weed population of 6.4, 5.2, 4.0, 4.2 and 4.4 per m^2 respectively which was less than pendimethalin @ 1000 ml/acre. Similar results that pre-emergence application of pendimethalin @ 2.5 l/ha within two days of sowing provided effective control of Phalaris minor in wheat (Kaur *et. al.*. 2014 and Anonymous. 2015).

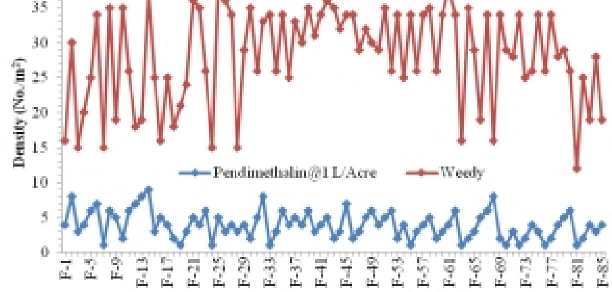

Fig 1 : Effect of pendimethalin on *Phalaris minor density* in different farmers field

Table 1: Bio-efficacy of different herbicides for control of Phalaris minor in wheat.

Treatments	Dose (g or ml/acre)	Density at harvest (No./m^2)	Dry matter at harvest (g/m^2)	Weed control efficiency at harvest (%)
Pendimethalin	1000	3.9	124.0	84.0
Clodinafop	160 to 300	6.4	241.6	68.8
Pinoxaden	400 to 500	5.2	201.0	74.1
Sulfosulfuron	13	4.0	150.5	80.6
Mesosulfuron + Iodosulfuron (Atlantis)	160 to 200	4.2	165.0	78.7
Sulfosulfuron + Metsulfuron (Total)	16	4.4	186.2	76.0
Weed free	-	0.0	0.0	100.0
Weedy	-	28.1	775.5	0.0

Weed dry weight

The application of pendimethalin @ 1000 ml/acre in different fields of farmers recorded less dry weight of Phalaris minor as compared to weedy check. The dry weight of Phalaris minor ranges from 31 to 270 g/m2 in farmers' fields treated with pendimethalin @ 1000 ml/acre while it ranges from 436 to 978 g/m2 in weedy plots of farmers (fig.2). On comparison with farmers' practices, it was recorded that the application of pendimethalin @ 1000 ml/acre resulted less dry weight of Phalaris minor as compared to other farmers practices [Clodinafop @160 to 300 g/acre, Pinoxaden 400 to 500 ml/acre, Sulfosulfuron @ 13 g/acre, Mesosulfuron + Iodosulfuron (Atlantis) @160 to 200 g/acre and Sulfosulfuron + Metsulfuron (Total) @ 16g/acre] (table-1). The average dry weight of Phalaris minor Phalaris minor was 124 g/ m2 in farmers fields treated with pendimethalin @ 1000 ml/acre while 775.5 g/m2 in weedy plots of farmers. In different farmers practices, Clodinafop @160 to 300 g/acre, Pinoxaden 400 to 500 ml/acre, Sulfosulfuron @ 13 g/acre, Mesosulfuron + Iodosulfuron (Atlantis) @160 to 200 g/acre and Sulfosulfuron + Metsulfuron (Total) @ 16g/acre results average 241.6, 201.0, 150.5, 165.0 and 186.2 g/m2 respectively which were less than pendimethalin @ 1000 ml/acre. Similar result was reported by (Kaur *et al,* 2014 and Anonymous, 2015).

Weed control efficiency (WCE)

The highest weed control efficiency was recorded under weed free treatment (table 1). The weed control efficiency (WCE) ranges from 59 to 97 per cent in farmers' fields treated with pendimethalin @ 1000 ml/acre (fig.3). The average weed control efficiency (WCE) was 84 per cent in farmers fields treated with pendimethalin @ 1000 ml/acre while farmers practices *i.e.* Clodinafop @160 to 300 g/acre, Pinoxaden 400 to 500 ml/acre, Sulfosulfuron @ 13 g/acre, Mesosulfuron + Iodosulfuron (Atlantis) @160 to 200 g/acre and Sulfosulfuron + Metsulfuron (Total) @ 16g/acre results average 68.8, 74.1, 80.6, 78.7 and 76.0 per cent respectively which was less than pendimethalin @ 1000 ml/acre. The higher WCE is attributed to lower dry weight of weeds under pendimethalin @ 1000 ml/acre. Similar result was reported by Kaur *et. al.,* 2014.

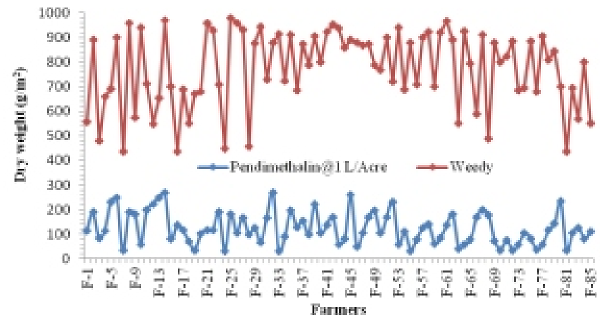

Fig 2 : Effect of pendimethalin on dry weight *of Phalaris minor density* in different field of farmers

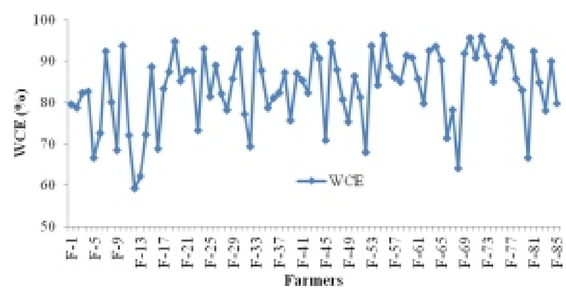

Fig 3 : Effect of pendimethalin on weed control efficency (WCE) of Phalaris minor in different farmers fields

Growth parameters

The maximum plant height and effective tillers were recorded with weed free plots followed by pendimethalin @ 1000 ml/acre Table 2. The respective average plant height and effective tillers 104.5 cm and 385.8 per m2 was observed with pendimethalin @ 1000 ml/acre which was more than other farmers practices i.e. Clodinafop @160 to 300 g/acre, Pinoxaden 400 to 500 ml/acre, Sulfosulfuron @ 13 g/acre, Mesosulfuron + Iodosulfuron (Atlantis) @160 to 200 g/acre and Sulfosulfuron + Metsulfuron (Total) @ 16g/acre. The weedy plots in farmers fields result less plant height and effective tillers as compared to other methods of weed control *i.e.* pendimethalin @ 1000 ml/acre, Clodinafop @160 to 300 g/acre, Pinoxaden 400 to 500 ml/acre, Sulfosulfuron @ 13 g/acre, Mesosulfuron + Iodosulfuron (Atlantis) @160 to 200 g/acre and Sulfosulfuron + Metsulfuron (Total) @ 16g/acre. Similar result was reported by Kaur *et. al.,* 2014.

Grain yield

The maximum grain yield was recorded with weed free plots followed by pendimethalin @ 1000 ml/acre Table 2. The grain yield in eighty five farmers' fields treated with pendimethalin @ 1000 ml/acre ranges from 16.5 to 25.5 q/acre (fig.4).On comparison with farmers' practices, it was recorded that the application of pendimethalin @ 1000 ml/acre resulted more grain yield as compared to other farmers practices [Clodinafop @160 to 300 g/acre, Pinoxaden 400 to 500 ml/acre, Sulfosulfuron @ 13 g/acre, Mesosulfuron + Iodosulfuron (Atlantis) @160 to 200 g/acre and Sulfosulfuron + Metsulfuron (Total) @ 16g/acre] (table-1). The average grain yield in different farmers fields treated with pendimethalin @ 1000 ml/acre was 22.0 q/acre while 16.9 q/acre in weedy plots of farmers. In different farmers practices, Clodinafop @160 to 300 g/acre, Pinoxaden 400 to 500 ml/acre, Sulfosulfuron @ 13 g/acre, Mesosulfuron + Iodosulfuron (Atlantis) @160 to 200 g/acre and Sulfosulfuron + Metsulfuron (Total) @ 16g/acre results average grain yield of 18.8, 20.8, 21.8, 20.9 and 21.5 q/acre respectively which were less than pendimethalin @ 1000 ml/acre. Similar result was reported by Kaur *et. al.,* 2014.

Residual effect on succeeding crop

The application of pendimethalin @ 1000 ml/acre in wheat crop had no residual effect on growth and yield of succeeding crop (fodder maize, sesbania, rice, moong and cotton) as responded by 85 farmers. Kulmi, 2009 also reported similar result that pendimethalin in rabi season crop had no residual effects on succeeding crop of soybean [Glycine max (L.) Merrill], mungbean (Phaseolus radiata L.), cowpea [Vigna unguiculata (L.) Walp.], sorghum [Sorghum bicolor (L.) Moench] and maize (Zea mays L.) which can safely be grown in kharif season in the rotation. The farmers which used clodinafop @ 160 to 300 g/acre and axil (pinoxaden) @ 400 to 500 ml/ acre for weed control in wheat responded that these herbicides had no adverse affect on fodder maize, sesbania, rice, moong and cotton. The farmers adopted rice -wheat-moong, rice- -wheat- green manuring (Dhancha), rice- -wheat- maize (fodder), rice- wheat and cotton-wheat crop rotations and applied Atlantis (mesosulfuron + iodosulfuron) @ 160 to 200 g/acre, total (sulfosulfuron + metsulfuron) @ 16 g/acre and leader (Sulfosulfuron) @ 13 g in wheat responded that these herbicides has adverse affect on growth and fodder yield of maize crop while no residual effect on moong, dhancha, rice and cotton crop. Singh et al. 2003, Yadav *et. al.* 2004 and Kaur and Brar, 2014 reported similar result that sulfosulfuron applied in wheat caused residual toxicity to maize but not to transplanted rice, urdbean, mung bean and cotton.

Economics

The maximum cost of cultivation was recorded with weed free plots while lowest was in weedy field Table 2. Application of pendimethalin @1000 ml/acre results lowest cost of cultivation as compared to other weed control treatments [clodinafop @160 to 300 g/acre, pinoxaden 400 to 500 ml/acre, sulfosulfuron @ 13 g/acre, mesosulfuron + Iodosulfuron (Atlantis) @160 to 200 g/acre and sulfosulfuron + metsulfuron (Total) @ 16g/acre] in different farmers fields (table-1). The maximum gross return was observed with weed free plots which was followed by pendimethalin @1000 ml/acre. The maximum net return and benefit cost ratio was observed with pendimethalin @1000 ml/acre as compared to clodinafop @160 to 300 g/acre, pinoxaden 400 to 500 ml/acre, sulfosulfuron @ 13 g/acre, mesosulfuron + Iodosulfuron (Atlantis) @160 to 200 g/acre and sulfosulfuron + metsulfuron (Total) @ 16g/acre, weedy and weed free plot in different farmers' fields.

Table 2: Effect of different herbicides on growth, yield attributes, yield and economics of wheat crop.

Treatments	Dose (g or ml/acre)	Plant height at harvest (cm)	Effective tillers (No./m^2)	Grain yield (q/acre)	Cost of cultivation (₹ / acre)	Gross Return ₹ / acre)	Net return ₹ / acre)	B:C ratio
Pendimethalin	1000	104.5	385.8	22.0	14940	34320	19380	1.30
Clodinafop	160 to 300	97.8	340.0	18.8	15090	29328	14238	0.94
Pinoxaden	400 to 500	102.0	361.5	20.8	15390	32448	17058	1.11
Sulfosulfuron	13	98.6	380.0	21.8	14960	34008	19048	1.27
Mesosulfuron + Iodosulfuron (Atlantis)	160 to 200	100.6	375.5	20.9	15065	32604	17539	1.16
Sulfosulfuron + Metsulfuron (Total)	16	101.8	390.2	21.5	15040	33540	18500	1.23
Weed free	-	104.0	402.5	23.0	17400	35880	18480	1.06
Weedy	-	90.2	198.6	16.9	14589	26364	11775	0.81

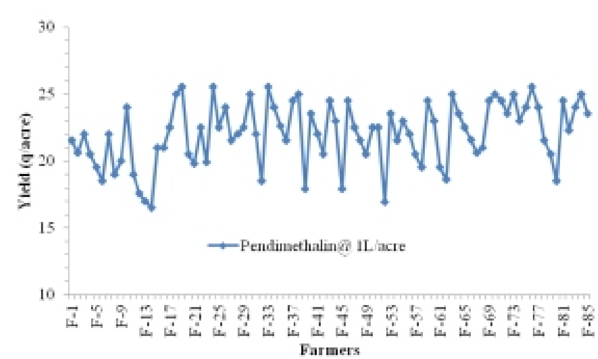

Fig 4 : Effect of pendimethalin on Grain yield of wheat at in different farmers field

Reasons for Non-Adoption

The different reasons cited by the non-adopters towards their decision of non-adoption of the pendimethalin for control of *Phalaris minor* in wheat are enlisted in Table 3. Lack of knowledge about pendimethalin for weed control in wheat was found to be the most important and frequently cited reason for the non-adoption (18.8%). Fear of low benefit: cost ratio (16.5%), busy schedule at the time of sowing (14.1%), lack of guidance for pendimethalin application (11.8%), fear of ineffectiveness of pendimethalin (10.6%) were the other major reasons towards non-adoption. Dissatisfaction with pendimethalin performance, fear of pendimethalin side effect on crop, less infestation of weed of Phalaris minor and non-availability of pendimethalin at sowing time were other reason responded by some farmers for non-adoption of pendimethalin for weed control in wheat. Altogether most of non-adopters did not go with the technology because of lack of knowledge and fear factors.

Table 3: Reason for non- adoption of pendimethalin for control of Phalaris minor in wheat crop

Reasons	No.	%	Range
Lack of knowledge about pendimethalin for weed control in wheat	16	18.8	I
Busy schedule at the time of sowing	12	14.1	III
Lack of guidance for pendimethalin application in wheat crop	10	11.8	IV
Less infestation of weed of *Phalaris minor*	6	7.1	VII
Fear of high cost involvement	3	3.5	VIII
Fear of pendimethalin side effect on crop	6	7.1	VII
Fear of ineffectiveness of pendimethalin	9	10.6	V
Fear of low benefit : cost ratio	14	16.5	II
Dissatisfaction with pendimethalin performance	7	8.2	VI
Non-availability of pendimethalin at sowing time	2	2.4	IX

Total no. of respondent farmers: 85

The results as given in table 4 indicate that there is urgent need of intensive extension work in this region to popularize the technology among the farming community. Most of the farmers had suggested publicising the details in respect to dose, time and method of application, safe handling measures, etc. through various extension activities. Besides that, the need of conducting intensive training programme on herbicide use in farmers' field was also felt as a crucial step for increasing the adoption level. A significant faction of the respondents (17.0%) wanted training by an extension personnel regarding the trade name of herbicides to be procured for a given kind of weed in a given crop, how to calculate quantity of herbicide and water to prepare the solution, spraying technique, stage of crop when herbicide is to be applied, and the precautions to be taken in respect to human and farm animal health hazards. The other important suggestion was easy availability of herbicides through co-operative society. The findings are in line with the observations as reported by Singh *et. al.* 2010.

Table 4: Farmers suggestion to bring improvements in adoption of pendimethalin for control of *Phalaris minor* in wheat.

Suggestions	Response (%)	Rank No
Intensive training on weed control in wheat crop	17.0	IV
Laying out more number of adoptive trails/ demonstration	33.0	I
Publicising detail instruction of handling, and time and method of use of herbicides.	19.0	III
Organising camps and field day for awareness about technology	27.0	II
Supply of herbicides through co-operative societies (No profit no loss basis)	4.0	V

Total no. of respondent farmers: 85

CONCLUSION

It was concluded that application of pendimethalin @ 1000 ml/acre resulted effective control of *Phalaris minor* and no residual effect on growth and yield of succeeding crops. Application of pendimethalin @ 1000 ml/acre also result more plant height, effective tillers, grain yield, net return and B: C ratio as compared to other farmers practices. Lack of detail knowledge, technical information and fear factors prevailing in the mind of farmers regarding pendimethalin use for control of Phalaris minor in wheat crop were the important reasons for non-adoption. Publicising the details in respect to dose, time and method of application and intensive training programme on herbicide use in farmers' field were felt as some crucial steps for increasing the adoption level.

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