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RESEARCH ARTICLE :

Field efficacy of *Pseudomonas fluorescens* against the cotton aphid, *Aphis gossypii* Glover (Hemiptera: Aphididae) in Bt and non Bt cotton

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SUMMARY : The cotton aphid, *Aphis gossypii* Glover (Hemiptera: Aphididae), is a key pest of cotton, irrespective of the use of conventional or organic management. In organic systems, however, the use of synthetic insecticides is not allowed, increasing the difficulty of controlling this pest. This work evaluated aphid control and the ability of products to prevent aphid infestation using entomopathogenic bacteria, *Pseudomonas fluorescens* compared to a standard synthetic insecticide. The trial was conducted with entomopathogenic fungi, *Beauveria bassiana* and untreated plants served as the control group. The trial testing the efficacy of *P. fluorescens* in preventing aphid infestation was conducted using the same products. The evaluations were conducted pre and post-treatment of three round of application for the efficacy and the protection against colonization trials, respectively. The lowest aphid populations recorded by the bio inoculant treatment of the soil and foliar application of *P. fluorescens* @1%. Regarding the plant protection against aphid colonization, the insecticide imidacloprid exhibited a better performance compared to the other tested products with steady results over the evaluation period. The other treatments exhibited variable results with protection against aphid colonization throughout the evaluation period.

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BACKGROUND AND OBJECTIVES

Cotton (*Gossypium* spp.) is one of the most important cash crops playing a key role in Indian economy and is unanimously designated as king of fibre crops. It is known in India from ancient days and its fabric is as old as 3000 B.C. It is an important fibre crop of global significance cultivated in more than seventy countries. It is an important raw material for the Indian textile industry and plays a key role in the national economy in terms of both employment generation and foreign exchange.

In India it is being cultivated in 11.70 m ha with a production of 25.50 m bales and productivity of 475 kg/ha (AICCIP, 2012-13). In India, the average production is very low in comparison to other countries and this is due to heavy damage caused by insect pests.

Cotton is being ravaged by several insect pests contributing to drastic reduction in yield. As many as 1,326 insect and mite pests in cotton all over the world (Manjunath, 2004). Among the cotton pests, the cotton aphid, Aphis *Gossypii* Glover is an important pest that infests at the beginning of the crop season, delaying early plant development; the aphid infestation might extend through the development of the plants if control practices are not adopted. Plants infested with cotton aphids exhibit reduced development and curled leaves, especially the young leaves driving the growth of the main stem and the leaves of the reproductive branches (Ebert, 2008 and Leclant and Deguine, 1994). Beyond the damage caused directly to the plant due to the feeding behaviour, aphids secrete honeydew on the leaves and the open lint, seriously endangering the cotton yield. In addition, the honeydew favours the development of black sooty mould fungus, which affects plant development and results in stick lint, causing problems during the spinning process at the textile mills (Deguine *et al.,* 2000). Large colonies of cotton aphids are commonly produced due to the intrinsic biotic characteristic s of the insects, such as rapid development and a parthenogenic mode of reproduction in the tropics, which are enhanced when coupled with high temperatures and plants under water stress (Godfrey *et al*., 2000 and Vanemden and Harrington, 2007), both of which are common environmental conditions in semiarid regions.

Aphid is a polyphagous pest species found on a variety of crop plants including cotton, cucumber, okra, and tomato (Ebert and Cartwright, 1997). High aphid populations can have negative impacts on cotton yield and result in economic losses (Andrews and Kitten, 1989, Harrisetal *et al.,* 1992 and Rosenheim *et al.,* 1995). In 1991, the cotton aphid was the number one pest species in domestic cotton, causing a yield loss of 2% (Head, 1992). Even small populations of late-season aphids are potentially damaging. Honeydew production during boll set may result in "sticky cotton" that can decrease cotton lint quality (Carter, 1992). Additionally, cotton aphids can vector 50 plant viruses (Kennedy *et al.,* 1962).

The control of cotton aphids in cotton fields is primarily addressed with seed treatment or foliar spraying with systemic or contact broad-spectrum insecticides (Almeida *et al*., 2008 and Torres and Silva -Torres, 2008). With the changes in agronomical practices after the introduction of Bt cotton genotype for commercial cultivation. The Bt toxin can effectively control specific lepidopteron species but lack resistance against sucking pests, aphid, leafhopper, thrips and whitefly (Hofs *et al.,* 2004 and Sharma and Pampathy, 2006). In impact assessment of transgenic cotton a little attention has been given on the changing dynamics of sucking pests and other non-target organism with Bt cotton it has been experienced that reduction in usage of insecticides lead to increased population of sucking insect pest (Men *et al.,* 2005).

Therefore there is an urgent need to replace pesticides with alternative means of control that are safe, low in cost, local in production and also environment friendly. Bio-pesticides or biological pesticide on pathogenic micro-organisms specific to a target pest offer an ecologically sound and effective solution to pest problems. They pose less threat to the environment and to human health.

Microbial insecticides such as entomopathogenic bacteria and fungi can provide an alternative, more environmentally friendly option to control this insect pest. The entomopathogenic bacteria, *Pseudomonas fluorescens* and fungi, *Beauveria bassiana* is a promising and extensively researched biological control agent that can suppress a variety of economically important insect pests (Coates *et al*., 2002; McGuire *et al*., 2005; Prasad and Syed, 2010 and Hussein *et al*., 2010). Sprays and soil application of pesticides are costly and cumbersome to adopt. So it is imperative to find out an ecofriendly and need based use of chemical pesticides as a component of integrated pest management (IPM). Until very recently, insecticidal activities in the *P. fluorescens* group had only been sparsely documented. Notably, strains of *P. fluorescens* were reported to exhibit insecticidal activity toward agricultural pest insects such as aphids (Hashimoto, 2002), phytophagous ladybird beetles (Otsu *et al.,* 2004) and termites (Devi and Kothamasi, 2009).

Based on the requirements for organic production, the utilization of natural insecticides is one way to control cotton aphid. Therefore, this study investigated the control of cotton aphids established on cotton plants and the ability of the treatment to prevent the colonization of treated plants. The tested product was a commercial formulation of *P. fluorescens* in comparison to *B. bassiana* and imidacloprid, a synthetic insecticide recommended to control cotton aphid in conventional cotton fields.

RESOURCES AND METHODS

Two field experiments were carried out during winter season in 2013- 14 to 2014-15 at Vanavarayar Institute of Agriculture (VIA), Mankkadavu, Pollachi, Coimbatore district of Tamil Nadu and South Indian millers Association, Udumelpet, Tiruppur. The experiments were configured with seven treatments which were replicated four times. Cotton hybrid Bt cotton (RCH 20) and Non Bt cotton (LRA 5166) were sown in a plot size 5 x 4 m with spacing of 90 x 60 cm. The crop was raised following all standard agronomical practices. The treatments were imposed as and when aphid crossed ETL, ten nymphs or adults of aphids per leaf.

A total of seven treatments were imposed in the two years trial with cotton hybrids T_1- Foliar application of *P. fluorescens* @1%, T_2 - Soil application of *P. fluorescens* 2.5 kg/ha, T_3 – Soil and Foliar application of *P. fluorescens* @1%, T_4 – Foliar application of *P. fluorescens* @1% and *Beauveria basianna* @ 1%, T_5 - Foliar application of *Beauveria basianna* @ 1%, T_6 – imidacloprid 200 SL @ 200ml/ha and T_7 – Untreated check.

The spray materials were prepared at their recommended doses and spray the bio inoculants by knapsack sprayer. The population of sucking pest, aphids from each plot was recorded 24 hrs before and after spray of bio inoculants from ten randomly selected plants. The populations of aphids were recorded from top, middle and bottom leaves of the plants and averaged as per plant of the insects.

Statistical analysis :

The data collected were transformed into square root value as per the standard requisites (Gomez and Gomez, 1984). The experiments were subjected to statistical scrutiny following the method of Panse and Sukhatme (1989) and the means were compared with Least Significant Difference.

OBSERVATIONS AND ANALYSIS

The results obtained from the present study as well as discussions have been summarized under following heads:

Season I – Bt cotton field trial at VIA :

Observations recorded on the aphid population prior to treatments showed that the difference was not significant. The pretreatment population of aphid recorded in imidacloprid treated plot was 44.8 aphids per plant. The population recorded after first spray was 18.32 aphids per plant, after second spray it was 16.02 aphids per plant and after third spray it was 14.41 aphids per plant.

Table 1 : Evaluation of *P. fluorescens* against aphids, *Aphis gossypii* in Bt cotton (2013-14)

Treatments	Number of Aphids/ 3 leaves / plant									
	VIA					SIMA				
	PTC	1st spray	2nd spray	3rd spray	Mean	PTC	1st spray	2nd spray	3rd spray	Mean
Foliar application of P. fluorescens @1%	45.2 (6.72)	32.26 (5.68)	28.16 (5.31)	18.72 (4.33)	26.38 (5.14)	40.50 (6.36)	22.36 (4.73)	18.52 (4.30)	13.75 (3.71)	18.21 (4.27)
Soil application of P. fluorescens 2.5 kg/ha	49.0 (7.00)	30.45 (5.52)	25.33 (5.03)	24.02 (4.90)	26.60 (5.16)	42.65 (6.53)	23.76 (4.87)	19.13 (4.37)	13.96 (3.74)	18.95 (4.35)
Soil and Foliar application of P. fluorescens @1%	45.0 (6.71)	25.15 (5.01)	16.47 (4.06)	15.21 (3.90)	19.55 (4.42)	39.75 (6.30)	15.64 (3.95)	13.58 (3.68)	8.91 (2.98)	12.71 (3.57)
Foliar application of P. fluorescens @1% and *Beauveria basianna* @ 1%	47.5 (6.89)	27.42 (5.24)	20.54 (4.53)	15.17 (3.90)	21.45 (4.63)	40.29 (6.35)	16.49 (4.06)	15.34 (3.92)	14.19 (3.77)	15.34 (3.92)
Foliar application of Beauveria basianna @ 1%	45.5 (6.74)	28.06 (5.30)	23.16 (4.81)	20.84 (4.56)	23.05 (4.80)	41.66 (6.45)	18.85 (4.34)	16.37 (4.05)	15.36 (3.92)	16.86 (4.11)
imidacloprid 200 SL @ 200ml/ha	44.8 (6.69)	18.32 (4.28)	16.02 (4.00)	14.41 (3.80)	16.40 (4.05)	41.97 (6.48)	12.28 (3.50)	8.57 (2.93)	8.97 (2.99)	8.94 (2.99)
Untreated check	47.0 (6.86)	52.96 (7.28)	62.86 (7.93)	55.63 (7.46)	57.15 (7.56)	41.59 (6.45)	45.83 (6.77)	52.86 (7.27)	49.90 (7.06)	49.53 (7.04)
S.E.±	NS	0.039	0.038	0.0453	0.0308	NS	0.0336	0.0332	0.0379	0.0310
C.D. (P=0.05)		0.081	0.080	0.0952	0.0647		0.0706	0.0696	0.0796	0.0651
F		1114.04	2454.21	1609.72	2785.87		1999.23	3420.54	2705.41	3452.53

VIA: Vanavarayar Institute of Agriculture, Pollachi SIMA: South Indian Millers Association, Udumelpet.
PTC: Pretreatment count,. Figures in parentheses are square root transformed values NS=Non-significant

Among bio inoculants the soil and foliar application of *P. fluorescens* @ 1 % reduced population of aphid by 65.7 per cent after three spray applications (Fig.1). The pretreatment population of aphid recorded was 45.0 aphids per plant, after first spray 25.15 aphids per plant after second spray it was 16.47 aphids per plant and 15.21 aphids after third spray application, respectively (Table 1).

Season I - Bt cotton field trial at SIMA :

In all the observations on aphid population caused a significant reduction in the aphid population throughout and recorded a pooled mean of 8.94 to 18.95 aphids per plant, respectively (Table 1), with 81.65 to 61.74 per cent reduction over control after three round of spray (Fig. 1). After three observations the standard chemical insecticide was found to be significantly more effective followed by the soil and foliar application of *P. fluorescens* @ 1 % was next better treatment among the bio inoculants.

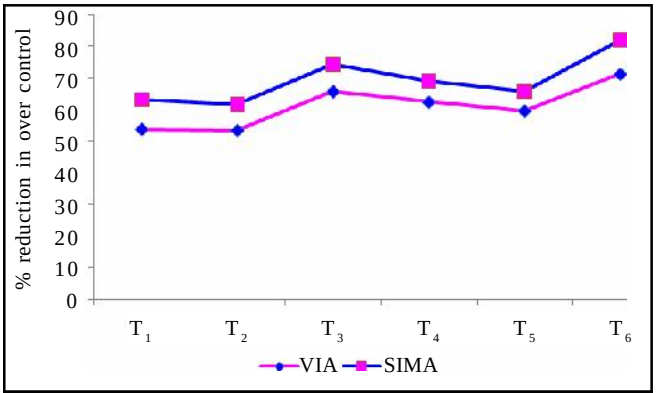

Fig. 1 : Per cent reduction in aphid population by after application of three spray in Bt cotton trial in VIA (Season I -2013-14)

Season I – Non Bt cotton field trial at VIA :

Field trial at VIA, the evaluation of aphid infestation on cotton plants prior to bio inoculant treatment application resulted in a statistically similar average of aphids per plant. Among the treatments, the synthetic insecticide imidacloprid exhibited the best performance in protecting the plants against aphid colonization. Followed by soil and foliar application of *P. fluorescens* @ 1 % was found to be the best effective in reducing the aphid population and recorded a pooled mean of 11.67 aphids per plant with 74. 36% reduction compared to the control (Table 2 and Fig. 2). The other treatments could be arranged descending as follows foliar application of *P. fluorescens* @1% and *B. basianna* @ 1% (65.33%), Foliar application of *B. basianna* @ 1% (61.70 %), Foliar application of *P. fluorescens* @1% (58.457 %), Soil application of *P. fluorescens* 2.5 kg/ha (57.069%).

Table 2 : Evaluation of *P. fluorescens* against aphids, *Aphis gossypii* in non Bt cotton (2013-14)

Treatments	Number of Aphids/ 3 leaves / plant									
	VIA					SIMA				
	PTC	1st spray	2nd spray	3rd spray	Mean	PTC	1st spray	2nd spray	3rd spray	Mean
Foliar application of *P. fluorescens* @1%	38.12 (6.17)	23.54 (4.85)	19.38 (4.40)	13.81 (3.72)	18.91 (4.35)	37.36 (6.11)	18.49 (4.30)	12.35 (3.51)	8.73 (2.95)	13.19 (3.63)
Soil application of *P. fluorescens* 2.5 kg/ha	37.16 (6.10)	24.12 (4.91)	20.59 (4.54)	13.91 (3.73)	19.54 (4.42)	36.89 (6.07)	19.22 (4.38)	13.05 (3.61)	9.37 (3.06)	13.88 (3.73)
Soil and Foliar application of *P. fluorescens* @1%	35.43 (5.95)	18.46 (4.30)	9.54 (3.09)	7.01 (2.65)	11.67 (3.42)	36.54 (6.04)	12.98 (3.60)	6.57 (2.56)	4.99 (2.23)	8.18 (2.86)
Foliar application of P. fluorescens @1% and *Beauveria basianna* @ 1%	37.88 (6.15)	19.01 (4.36)	16.99 (4.12)	11.34 (3.37)	15.78 (3.97)	36.22 (6.02)	15.83 (3.98)	9.41 (3.07)	5.63 (2.37)	10.29 (3.21)
Foliar application of *Beauveria basianna* @ 1%	36.94 (6.08)	20.28 (4.50)	18.59 (4.31)	13.42 (3.66)	17.43 (4.17)	37.13 (6.09)	17.62 (4.20)	12.97 (3.60)	7.6 (2.76)	12.73 (3.57)
Imidacloprid 200 SL @ 200ml/ha	35.94 (5.99)	10.33 (3.21)	6.29 (2.51)	3.87 (1.97)	6.83 (2.61)	37.82 (6.15)	8.49 (2.91)	3.89 (1.97)	1.48 (1.22)	4.62 (2.15)
Untreated check	36.67 (6.06)	39.58 (6.29)	45.74 (6.76)	51.21 (7.16)	45.51 (8.57)	36.47 (6.04)	42.36 (6.51)	44.75 (6.69)	48.88 (6.99)	45.33 (6.73)
S.E.±	NS	0.0272	0.0387	0.0238	0.0312	NS	0.0279	0.0120	0.0187	0.0197
C.D. (P=0.05)		0.0570	0.0812	0.0501	0.0655		0.0586	0.0252	0.0392	0.0414
F		2302.92	2412.52	9478.27	3339.90		3172.84	31467.27	19253.59	10791.02

VIA: Vanavarayar Institute of Agriculture, Pollachi SIMA: South Indian Millers Association, Udumelpet.
PTC: Pretreatment count, Figures in parentheses are square root transformed values NS=Non-significant

Season I – Non Bt cotton field trial at SIMA :

After the first spray, among the bio inoculants treatment the lowest aphid population recorded in soil and foliar application of *P.fluorescens* @ 1 % (12.98 aphid/ plant), followed by foliar application of *P. fluorescens* @1% and *B. basianna* @ 1% (15.83 aphid/ plant) which was on par with foliar application of *B. basianna* @ 1% (17.62 aphid/ plant). However, untreated check recorded the highest population of 42.36 aphids per plant. The trend was similar for second and third round of application (Table 2). After three observations the soil and foliar application of *P.fluorescens* @ 1 % was recorded a pooled mean of 8.18 aphids per plant, respectively with 81.95 per cent reduction over control (Fig. 2).

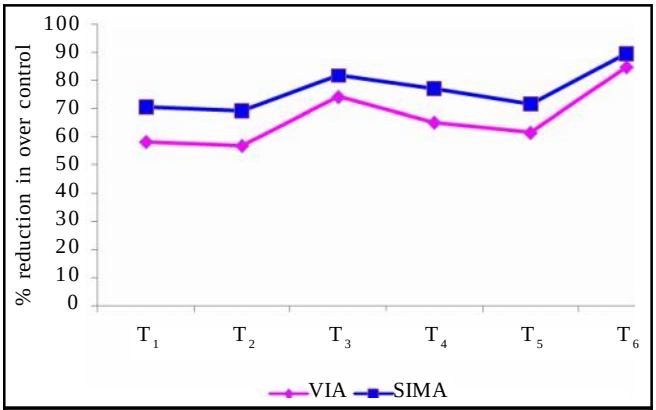

Fig. 2 : Per cent reduction in aphid population by after application of three spray in non Bt cotton trial in VIA (Season I -2013-14)

Season II - Bt cotton field trial at VIA :

Recorded the aphid population among the different treatments lowest population was recorded 16.41 aphids per plant on chemical insecticide, imidacloprid. The highest population of aphids was observed in untreated check which registered 39.84 aphids per plant after first spray. In case of bio inoculant, the soil and foliar application of *P. fluorescens* @ 1 % (20.29 aphids / plant) and foliar application of *P. fluorescens* @ 1 % and *B. basianna* @ 1 % (22.43 aphids/ plant) were effective treatments after the first spray of application (Table 3). After second and third round of sprays the soil and foliar application of *P. fluorescens* @ 1 % treatment recorded 18.45 and 7.24 aphids per plant, respectively. The highest aphid reduction over control 59.2 per cent recorded in the plot treated with the soil and foliar application of *P.fluorescens* @ 1 % and was at par with foliar application of *P.fluorescens* @ 1 % and *B. basianna* @ 1 % (53.73%) (Fig. 3).

Season II – Bt cotton field trial at SIMA :

The evaluation of aphid infestation on cotton plants prior to bio inoculant treatment application resulted in a

Table 3 : Evaluation of *P. fluorescens* against aphids, *Aphis gossypii* in Bt cotton (2014-15)

Treatments	Number of Aphids/ 3 leaves / plant									
	VIA					SIMA				
	PTC	1st spray	2nd spray	3rd spray	Mean	PTC	1st spray	2nd spray	3rd spray	Mean
Foliar application of *P. fluorescens* @1%	40.6 (6.37)	27.64 (5.26)	23.57 (4.85)	16.78 (4.10)	22.9 (4.78)	38.56 (6.21)	21.37 (4.62)	14.63 (3.82)	11.73 (3.42)	15.91 (3.99)
Soil application of *P. fluorescens* 2.5 kg/ha	35.6 (5.97)	28.35 (5.32)	24.63 (4.96)	13.73 (3.71)	22.0 (4.69)	38.72 (6.22)	21.87 (4.68)	15.02 (3.88)	12.67 (3.56)	16.52 (4.06)
Soil and Foliar application of *P. fluorescens* @1%	40.9 (6.39)	20.29 (4.50)	18.45 (4.30)	7.24 (2.69)	16.4 (4.05)	37.41 (6.12)	16.45 (4.06)	10.53 (3.24)	7.37 (2.71)	11.45 (3.38)
Foliar application of *P. fluorescens* @1% and *Beauveria basianna* @1%	35.1 (5.92)	22.43 (4.74)	19.67 (4.44)	15.84 (3.98)	18.6 (4.31)	37.65 (6.14)	17.23 (4.15)	14.22 (3.77)	9.89 (3.14)	13.78 (3.71)
Foliar application of *Beauveria basianna* @ 1%	37.3 (6.11)	23.51 (4.85)	20.79 (4.56)	19.18 (4.38)	20.8 (4.56)	38.66 (6.22)	18.16 (4.26)	15.73 (3.97)	11.92 (3.45)	15.27 (3.91)
Imidacloprid 200 SL @ 200ml/ha	33.5 (5.79)	16.41 (4.05)	10.94 (3.31)	6.55 (2.56)	11.3 (3.37)	37.89 (6.16)	10.98 (3.31)	7.34 (2.71)	4.57 (2.14)	7.63 (2.76)
Untreated check	36.5 (6.04)	39.84 (6.31)	41.23 (6.42)	39.53 (6.29)	40.2 (6.34)	36.44 (6.04)	40.29 (6.35)	45.86 (6.77)	49.84 (7.06)	45.33 (6.73)
S.E.±	NS	0.0390	0.0357	0.0348	0.0341	NS	0.2151	0.0302	0.0198	0.0173
C.D. (P=.05)		0.0820	0.0751	0.0731	0.0717		0.4519	0.0635	0.0416	0.0363
F		685.28	1369.21	2546.03	1420.41		3719.91	3652.31	12886.05	10539.28

VIA: Vanavarayar Institute of Agriculture, Pollachi SIMA: South Indian Millers Association, Udumelpet.
PTC: Pretreatment count, Figures in parentheses are square root transformed values NS=Non-significant

statistically similar average of aphids per plant. Among the treatments the aphid population recorded at first spray was minimum in the plots treated with the synthetic insecticide imidacloprid (10.98 aphids/ plant) and was par with soil and foliar application of *P. fluorescens* @ 1 % (16.45 aphids /plant). The same trend of efficacy was observed after second and third treatment sprays (Table 3), among the various bio inoculants treatments soil and foliar application of *P. fluorescens* @ 1 % showed 74.74 percent reduction of aphid population. Next better effective treatment was foliar application of *P. fluorescens* @ 1 % and *B. basianna* @ 1 % (69.60%) and was at par with foliar application of *P. fluorescens* @ 1 % (66.31%) (Fig. 3).

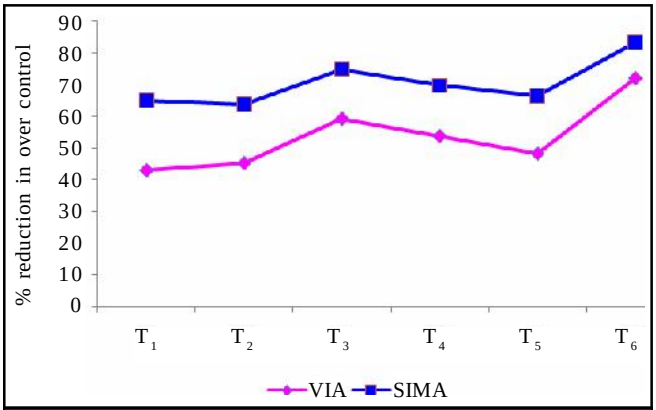

Fig. 3 : Percent reduction in aphid population by after application of three spray in Bt cotton trial in VIA (Season II -2014-15)

Season II – Non Bt cotton field trial at VIA :

After first spray the lowest incidence of aphids was recorded from the plots treated with of imidacloprid (9.24 aphids /plant) with 86.40 per cent reduction over control followed by soil and foliar application of *P. fluorescens* @ 1 % (14.28 aphids /plant) with 75.30 per cent reduction over control (Fig. 4.). The next promising treatments in minimizing aphid population were foliar application of *P. fluorescens* @ 1 % and foliar application of *B. basianna* @ 1 % (15.87 aphids /plant) and foliar application of *B. basianna* @ 1 % (18.96 aphids/ plant). Statically all these treatments were found at par. Moreover, maximum incidence of (37.29 aphids /plant) was observed from untreated check. The trend was similar for second and third round of application (Table 4).

Season II – Non Bt cotton field trial at SIMA :

The pooled average indicated that imidacloprid recorded lowest population of aphids (5.66 aphids /plant) with 86.42 per cent population reduction over control followed by soil and foliar application of *P. fluorescens* @ 1 % (7.65 aphids /plant) with 81.65 per cent population reduction over control (Fig. 4). The other treatments in

Table 4 : Evaluation of *P. fluorescens* against aphids, *Aphis gossypii* in non Bt cotton (2014-15)

Treatments	Number of Aphids/ 3 leaves / plant									
	VIA					SIMA				
	PTC	1st spray	2nd spray	3rd spray	Mean	PTC	1st spray	2nd spray	3rd spray	Mean
Foliar application of *P. fluorescens* @1%	33.64 (5.80)	21.57 (4.64)	16.42 (4.05)	9.98 (3.16)	15.99 (4.00)	34.42 (5.87)	15.38 (3.92)	13.67 (3.70)	7.49 (2.74)	12.18 (3.49)
Soil application of *P. fluorescens* 2.5 kg/ha	32.75 (5.72)	22.34 (4.73)	17.59 (4.19)	10.62 (3.26)	16.85 (4.10)	35.98 (6.00)	16.51 (4.06)	14.72 (3.84)	9.09 (3.02)	13.44 (3.67)
Soil and Foliar application of *P. fluorescens* @1%	33.48 (5.79)	14.28 (3.78)	10.34 (3.22)	6.76 (2.60)	10.46 (3.23)	35.14 (5.93)	10.57 (3.25)	7.83 (2.80)	4.55 (2.13)	7.65 (2.77)
Foliar application of *P. fluorescens* @1% and *Beauveria basianna* @1%	32.89 (5.73)	15.87 (3.98)	13.59 (3.69)	11.67 (3.42)	13.71 (3.70)	34.98 (5.91)	11.83 (3.44)	10.04 (3.17)	7.05 (2.65)	9.64 (3.10)
Foliar application of *Beauveria basianna* @ 1%	33.73 (5.81)	18.96 (4.35)	14.25 (3.77)	13.05 (3.61)	15.42 (3.93)	34.75 (5.89)	15.94 (3.99)	12.36 (3.52)	7.26 (2.69)	11.52 (3.39)
Imidacloprid 200 SL @ 200ml/ha	33.56 (5.79)	9.24 (3.04)	5.22 (2.28)	2.82 (1.68)	5.76 (2.40)	34.69 (5.89)	7.58 (2.75)	5.84 (2.42)	3.56 (1.89)	5.66 (2.38)
Untreated check	32.19 (5.67)	37.29 (6.11)	44.34 (6.66)	45.39 (6.74)	42.34 (6.51)	35.44 (5.95)	40.29 (6.35)	43.57 (6.60)	41.18 (6.42)	41.68 (6.46)
S.E.±	NS	0.0295	0.0328	0.0334	0.0224		0.0274	0.0279	0.0354	0.0305
C.D. (P=0.05)		0.0620	0.0690	0.0701	0.0471	NS	0.0575	0.0586	0.0744	0.0641
F		2100.36	3341.81	4428.69	6310.01		3534.17	4799.96	3694.49	3809.05

VIA: Vanavarayar Institute of Agriculture, Pollachi SIMA: South Indian Millers Association, Udumelpet.
PTC: Pretreatment count, Figures in parentheses are square root transformed values NS=Non-significant

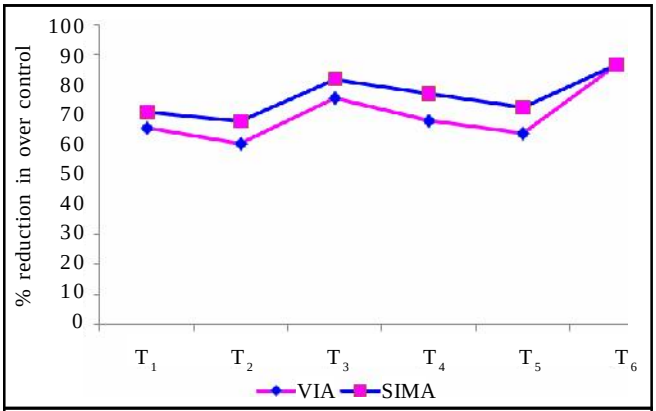

Fig. 4 : Per cent reduction in aphid population by after application of three spray in non Bt cotton trial in VIA (Season II -2014-15)

order of reducing aphid population were foliar application of *P. fluorescens* @ 1 % and foliar application of *B. basianna* @ 1 % (9.64 aphids /plant) and foliar application of *B. basianna* @ 1 % (11.52 aphids/ plant). All these treatments were statistically at par with each other. The untreated check harbored more number of aphids (41.68 aphids/ plant) as compared to other treatments (Table 4).

The present results showed that the soil and foliar application of *P.fluorescens* @ 1 % have effectively kept level of sucking insect pests of cotton aphid below economic threshold levels comparison with other bio inoculants. *P. fluorescens* reduced the severity of aphid population upto 20 to 42 per cent in cotton and also enhanced plant height, number of bolls and increased yield as reported by Sakithivel *et al*. (1997), which was also confirmed by Milner (2000), who observed that foliar application of *P. fluorescens* @ 2ml/lit highly effective in reducing the aphids population in cotton.

It concurrence to the present study, seed treatment and foliar spray with *P.fluorescens* effectively controlled the aphid population and increased the cotton kapas yield reported by Vidhayasekaran (1999). Similar results was obtained by Gokee (2001) and Kim *et al.* (2001), who noted that study the bio efficacy of different entomopathogenic bacteria and fungi were found to be suited against cotton aphids.

Azadeh *et al*. (2014) conclude that the *Pseudomonas fluorescens* treatment had significant negative effects on population growth rate of *A. gossypii*. Also, the plants treated with these bacterial strains had a significant increase in yield weight of approximately 58%. Singh *et al*. (1994) reported that the application of *P. fluorescens* in rapeseed resulted in increased biomass production and accumulation of phenols and tannins in the plant tissue and decreased the incidence of aphid, *Lipaphis erysimi* (Kalt.). The similar results were obtained in mustard also with reduced infestation of aphid, *L. erysimi* in *P. fluorescens* treatment. Sujay *et al.* (2009) results revealed that the sucking pests *viz., S. dorsalis, P. latus* and *M. persicae*, were effectively controlled in eco-friendly plot which was on par with farmer's plot of applying chemical pesticides.

The results of two year trials revealed the potential of *P. fluorescens* as a microbial agent by causing significant mortality of cotton aphid in Bt cotton and Non Bt can be best utilized for ecofriendly IPM programme of either Bt cotton or conventional cotton cropping system.

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REFERENCES

AICCIP (2012-13). All India Coordinated Cotton Improvement Project, Coimbatore, Tamil Nadu - 641 003.

Almeida, R.P., Silva, A.C.D.A. and Ramalho, F.S. (2008). Manejo integrado de pragas do algodoeiro no Brasil. In: Beltrao, N.E.M. and Azevedo, D.M.P. (Ed.). O agronegócio do algodão no Brasil. Brasília: Embrapa. p. 1035-1098.

Andrews, G.L. and Kitten, W.F. (1989). How cotton yields are affected by aphid populations which occur during boll set, pp. 291Ð293. In Proceedings of the Belt wide Cotton Conferences, National Cotton Council of America, 2Ð7 January 1989, Memphis, TN.

Azadeh Fahimi, Ahmad Ashouri, Masoud Ahmadzadeh, Vahid Hoseini Naveh and Ahmad Asgharzadeh (2014). Effect of PGPR on population growth parameters of cotton aphid. *Archives*

Phytopathol. & Plant Protec., **47** (11) : 1274-1285.

Carter, F.L. (1992). The sticky cotton issue, p. 645. In Proceedings of the Belt wide Cotton Conferences, National Cotton Council of America, 6Ð10 January 1992, Memphis, TN

Coates, B.S., Hellmich, R.L. and Lewis, L.C. (2002). Allelic variation of a *Beauveria bassiana* (Ascomycotina: Hypocreales) minisatellite is independent of host range and geographic origin. *Genome,* **45**: 125 - 132.

Deguine, J. P., Goze, E. and Leclant, F. (2000). The consequences of late outbreaks of the aphid *Aphis gossypii* in cotton growing in Central Africa: towards a possible method for the prevention of cotton stickiness. *Internat. J. Pest Mgmt.,* **46** (1) : 85-89.

Devi, K.K. and Kothamasi, D. (2009). *Pseudomonas fluorescens* CHA0 can kill subterranean termite *Odontotermes obesus* by inhibiting cytochrome c oxidase of the termite respiratory chain. *FEMS Microbiol. Lett.,* **300** : 195–200 10.1111/j.1574-6968.2009.01782.x

Ebert, T.A. (2008). Melon aphid. *Aphis gossypii* (Hemiptera: Aphididae). In: Capinera, J. L. (Ed.). Encyclopedia of entomology. 2nd Ed. Dordrecht: Springer. v. **1-4**. p. 1374-1378.

Ebert, T.A. and Cartwright, B. (1997). Biology and ecology of Aphis gossypii Glover (Homoptera: Aphididae). *South-Western Entomol.,* **22**: 116Ð145.

Godfrey, L.D., Rosenhem , J.A. and Goodell, P.B. (2000). Cotton aphid emerges as major pest in SJV cotton. *California Agric.,* **54** (6) : 26-29.

Gokee, P. (2001). Evaluation of *Pseudomonas fluorescens* against cotton aphids. *Pesticide Res. J.,* **19** (2) : 218-221.

Gomez, A.K. and Gomez, A.A. (1984). *Statistical procedures for agricultural research*. John Wiley and Sons. Inc., Singapore.

Harris, F.A., Andrews, G.L. and Caillavet, D.F. (1992). Cotton aphid effect on yield, quality and economics of cotton, pp. 652Ð656. In Proceedings of the Beltwide Cotton Conferences, National Cotton Council of America, Memphis, TN.

Hashimoto, Y. (2002). Study of the bacteria pathogenic for aphids, isolation of bacteria and identification of insecticidal compound. *Rep. Hokkaido Prefectural Agric. Exp. Station* **102** : 1–48.

Head, R.B. (1992). Cotton insect losses 1991, pp. 621Ð625. In Proceedings of the Belt wide Cotton Conferences, National Cotton Council of America, 6Ð10 January 1992, Memphis, TN.

Hofs, J.I., Schoeman, A. and Vaisayre, M. (2004). Effect of Bt cotton on arthropod biodiversity in South Africon cotton fields. *Common Agri. Appl. Biol. Sci.,* **69** : 191-194.

Hussein, K. A., Abdel-Rahmann, M.A.A., Abdel-Mallek, A.Y., El-Maraghy, S.S. and Jin, Ho Joo (2010). Climatic factors interference with the occurrence of *Beauveria bassiana* and *Metarhizium anisopliae* in cultivated soil. *African J. Biotechnol.,* **9** (45): 7674-7682

Kennedy, J.S., Day, M.F. and Eastop, V.F. (1962). A conspectus of aphids as vectors of plant viruses. Commonwealth Institute of Entomology, London

Kim, N., Pandi, Pirasanna, Paul, G. Bishwajeet, Vivek, Shah and Shankarganesh, K. (2001). Biefficacy of *Pseudomonas fluorescens* and foliar application against tomato aphid, *Aphis gossypii* Glover. *Pestology ,* **67** (1): 16-20.

Leclant, F. and Deguine, J.P. (1994). Aphids (Hemiptera: Aphididae). In: Mattews, G.A. and Unstall, J.P. (Ed.). Insect pests of cotton. Wallingford: CAB International, p. 285-323.

Manjunath, T.M. (2004). Bt cotton in India: The technology wins as the controversy wanes. *http://www.Monsanto.co.uk/news/ukshowlib. html?wid=8478.*

McGuire, R.M., Mauricio Ulloa, Young-Hoon Park and Neal Hudson (2005). Biological and molecular characteristics of *Beauveria bassiana* isolates from California *Lygus hesperus* (Hemiptera: Miridae) populations. *Biological Control,* **33**: 307 - 314.

Men, X., Ge, F., Edwards, C.A. and Yardim, E.N. (2005). The influence of pesticides applications on *Helicoverpa armigera* and sucking pests in transgenic cotton and non-transgenic cotton in China. *Crop Prot.,* **24** : 319-324.

Milner, R.J. (2000). Current status of Metarhizium as mycoinsectiode in Austrialia. *Biocontrol News Inf.* 21 : 47N-50N.

Otsu, Y., Matsuda, Y., Mori, H., Ueki, H., Nakajima, T. and Fujiwara, K. (2004). Stable phylloplane colonization by entomopathogenic bacterium *Pseudomonas fluorescens* KPM-018P and biological control of phytophagous ladybird beetles *Epilachna vigintioctopunctata* (Coleoptera: Coccinellidae). *Biocontrol Sci. Technol.,* **14** : 427–439.

Panse, N.G. and Sukhatme, P.V. (1989). *Statistical methods for agricultural workers*. Indian council for Agricultural research, New Delhi. 359pp.

Prasad, A. and Syed, N. (2010). Evaluating prospects of fungal biopesticide *Beaveria bassiana* (Balsamo) against *Helicoverpa armigera* (Hubner): An ecosafe strategy for pesticide pollution. *Asian J. Experimental Biol. Sci.,* **1**(3): 596-601.

Rosenheim, J.A., Fuson, K.J. and Godfrey, L.D. (1995). Cotton aphid biology, pesticide resistance, and management in the San Joaquin Valley, pp. 97Ð101. In Proceedings of the Beltwide Cotton Conferences, National Cotton Council of America, 4Ð6

January 1995, Memphis, TN.

Sakthivel, J., Hakim, A.S., Mohammed Nadeen, S., Khalid Hussain, D. and Ghulam Mustafa S. (1997). Efficacy of *Pseudomonas fluorescens* against aphids in cotton crop. *Pesticide Res. J.,* **19** (2) : 114-119.

Sharma, H.C. and Pampathy, G. (2006). Influence of transgenic cotton on the relative abundance and damage by target and non-target insect pests under different protection regimes in India. *Crop Prot.,* **25**: 800-813.

Singh, C.P., Shrotia, P.K. Singh, K.N. and Pandey, M.C. (1994). Effect of green gold plus application on yield and aphid prevalence in rapeseed (*Brassica compestris*). *Pestol.*, **10**: 15-17

Sujay, Y.H., Dhandapani, N., Pushpa, V. and Giraddi , R.S. (2009). Evaluation of eco-friendly approaches for the management of sucking pests in chilli. *Karnataka J. Agric. Sci.,* **22**(3-Spl.Issue) : (720-721).

Torres, J.B. and Silva–Torres, C.S.A. (2008). Interação entre inseticidas e umidade do solo no controle do pulgão e da mosca-branca em algodoeiro. *Pesquisa Agropecuária Brasileira*, **43** (8) : 949-956.

Vanemden, H.F. and Harrington, R. (2007). Aphids as crop pests. Cambridge: CAB International, 2007.

Vidhyasekaran, P. (1999). Biological control of plant pathogens using fluorescent *Pseudomonas*. PP 57-58 In: *Mass Multiplication of Bio- control Agents* (Dhandapani, N., Devasenapathy, P., Ranghaswami, M.V. and Oliver, J. eds.) Directorate of Extension Education, Tamil Nadu Agricultural University. Coimbatore.