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# Efficacy of potassium salt of glyphosate on weed control and yield in transgenic corn

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ABSTRACT

A field experiment was carried out at Directorate of Weed Research, Jabalpur for the consecutive two years during *kharif* 2009 and 2010 to evaluate the weed control efficiency and crop productivity with K salt of glyphosate formulation in field conditions. Treatments consisted of two transgenic stacked hybrids named Hishell and 900M Gold applied with glyphosate as early post-emergence at 900, 1 800 and 3 600 g a.i./ha during *kharif* season of 2010 with two conventional hybrids namely Proagro-4640 and HQPM-1. Among the treatments, early post-emergence application of glyphosate at all doses registered lower weed density and higher weed control efficiency, i.e. 100% in all transgenic corn hybrids at 21 DAS and at harvest. Significantly higher numbers of cobs/plot were observed in transgenic hybrids as compared to conventional entries. While more cob length was observed with Hishell Transgenic hybrids at all doses as compared to 900 M Gold transgenic hybrids. Hishell transgenic hybrids at 3 600 g/ha registered significantly higher number of grains per row as compared to with its conventional control, 900 M Gold transgenic hybrid (1 800 g/ha), 900 M Gold conventional and national checks. Significantly higher values of 20 cob weight, 20 cob grain weight and total cob weight was observed with Hishell and 900 M Gold transgenic hybrids as compared to other conventional hybrid entries and national checks. Hishell and 900 M Gold transgenic hybrids performed better with regard to grain yield ranging between 6-10 tonnes/ha which was approximately 3 to 4 times higher than the average yield of maize crop per ha, i.e. 2.30 tonnes/ha during both the years. Hishell at all rates of glyphosate application performed equally well in terms of yield but the yield of 900 M Gold decreased as the dose was enhanced from 1 800 to 3 600 g/ha during second year of experimentation.

**Key words:** Glyphosate, Transgenic maize, Weed control efficiency, Yield

In India, maize (*Zea mays* L.) is grown in a wide range of environments, extending from extreme semi-arid to sub-humid and humid regions and can be classified into two production environments: (i) traditional maize growing areas, including Bihar, Madhya Pradesh, Rajasthan, and Uttar Pradesh, and (ii) non-traditional maize areas, including Karnataka and Andhra Pradesh. In diverse situation, like most cereals, this crop also faces some biotic and abiotic constraints to achieve the target production. Appropriate crop management can only make the production to the desirable levels. It is reported that the weeds and insects are the major constraints in the corn production. Weeds if not managed properly, may cause huge yield losses in the range of 40-60%.

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Emerging trend in Agricultural Biotechnology is a boon for the country. The evolution of herbicide tolerant crops by Monsanto may bring another revolution for the farmers in the country, Their "Roundup Ready" crops have been genetically engineered to permit direct, "over the top" application of the Monsanto herbicide glyphosate allowing farmers to drench both their crops and crop land with the herbicide so as to be able to kill nearby weeds (and any other green thing the herbicide touches) without killing the crops. The draw for farmers is the promised reduced cost, and increased yield and thus extra profit over traditional systems. *Bacillus thuringiensis*, commonly known as Bt, is a bacterium that occurs naturally in the soil. Herbicide tolerant and insect resistant genetically modified (GM) crop have become dominant fixtures in agro ecosystem of many of the worlds agricultural regions (James 2014) increasingly modifying the composition and dynamics of regional landscapes. When herbicide tolerant crop are employed as an integrated component of weed management than the entire system benefits including insect management. But when herbicide tolerant GM crop are marketed and employed with a mentality towards complete weed eradication, then numerous opportunities

for sustainable crop production and management are missed. (Lundgreen *et al.* 2009). Glyphosate, the most widely used herbicides in the world, is a nonselective post-emergence herbicides that controls a wide range of annual, biennial and perennial grass and broadleaf weeds (Franz *et al*. 1997, Woodburn 2000, Knezevic and Crassman 2003). It is absorbed throughout the plant, and inhibits 5-enolpyruvylshikimate-3-phosphate (EPSP) synthase, which prevents the production of tryptophane, tyrosine and phenylalanine in susceptible species (Senseman 2007).

Therefore, an experiment designed to study the bio-efficacy and residual study of glyphosate in transgenic corn (MON 89034X NK 603) to study the impact of transgenic stack corn (MON 89034X NK 603) hybrids against targeted weeds; to study the comparative assessment of soil eco-system and weediness, morphology and phenotypic characters of transgenic stack corn and its conventional counterpart hybrids; and to evaluate weed management efficiency with K-salt of glyphosate formulation under field conditions.

## MATERIALS AND METHODS

Field experiment was laid out during *kharif* seasons of 2009 and 2010 in Research Farm, Directorate of Weed Research located at Jabalpur, India. The geographical location of the experimental site is situated in Kymore plateau and Satpura Hills of Madhya Pradesh at 23°10'N latitude and 79° 57'E longitude with an altitude of 412 m above MSL and the farm receives the total annual rainfall of 1 253 mm during rainy days. The soil of the experimental site was medium black (Typic Haplustert) in texture and moderately alkaline with 177 kg/ha available nitrogen, 8 kg/ha available phosphorous and 478 kg/ha in available potassium with EC of 0.18 dS/m, pH of 6.3 and organic carbon of 0.9%.

The experiment was laid out in randomized complete block design (RBD) with sixteen treatments and replicated thrice. The gross plot size adopted was 18 $m^2$ (5 × 3.6 m). The adopted spacing between the rows and plants were 60 and 25 cm, respectively. Herbicide tolerant transgenic corn test hybrids namely Hishell and 900 M Gold, and conventional hybrids of conventional hybrids namely Proagro-4640 and HQPM-1 during the *kharif* season of 2009 and 2010. After sowing the seed, immediate light irrigation was given to the crop for uniform germination. The herbicide as glyphosate application at 2 to 4 leaf stage of weeds (20 to 25 days after sowing (DAS) of corn). Hand operated knapsack sprayer fitted with a flat fan type nozzle (WFN 40) was used for spraying the herbicides as per treatments schedule. Atrazin was applied as pre-emergence at third day after sowing, spraying of potassium salt of glyphosate (containing 500 g a.i/litre) was done at 900, 1 800 and 3 600 g a.i/ha at 20 DAS in both the seasons. Pre-calibrated amount of water was used to spray with the help of knapsack sprayer fitted with flat fan nozzle to ensure even distribution of herbicide in transgenic hybrid corn entries.The recommended dose of 150:75:75 kg of NPK/ ha are in the form of urea, di-ammonium phosphate and muriate of potash.

## RESULTS AND DISCUSSION

*Effect on weeds*

Observations on species-wise weed density (numbers/$m^2$) was recorded before K-salt application. Data presented in Table 1 indicated no definite trend at initial mean weed population was observed as no treatment was applied. However, Hishell Conventional (P) (T-7), National Check Conventional (P) (T-13) and Local check conventional (P) (T-15) showed significantly the lower weed density as compared to other treatments.

Weed flora of the experimental field in maize predominantly consist of 8 species of broad leaved weeds and grasses including sedges. The dominant weeds were *Echinochloa colona, Cyperus iria, Corchorus* sp.*, Phyllanthus niruri, Dinebra* sp.*, Physalis minima, Commelina benghalensis, Alternanthera sessilis.* The dominant grass weeds were *Echinochloa colona* and *Commelina benghalensis. Cyperus iria* was the only sedge recorded in the experimental field (Kannan and Chinnagounder 2014).

Different rates of glyphosate under transgenic maize hybrids recorded more than 90% control efficiency at 21 and at harvest. Whereas, at the same time PE application of atrazine in non-transgenic hybrids recorded only 23 to 59%. This might be due to the application of glyphosate which did not allow weeds to accumulate sufficient biomass and ultimately resulted in higher weed control efficiency (Kannan and Chinnagounder 2014). Proper application of glyphosate was effective in season-long control of *Echinochloa colona, Cyperus iria, Corchorus* sp.*, Phyllanthus niruri, Dinebra* sp.*, Physalis minima, Commelina benghalensis, Alternanthera sessilis* at at all the levels more than 90% of control throughout the season.

Weed density in transgenic and conventional corn hybrid were recorded at 13, 30 and 60 DAS (Table 2 and 3). Weed density at 13 days after sowing indicated the general state of weed infestation in all treatments. The K-salt of glyphosate was sprayed immediately after 25 DAS. Table 1 revealed that no definite trend at initial mean weed population as no treatment was applied. However, Hishell Conventional (P) (T-7), National Check Conventional (P) (T-13) and Local check conventional (P) (T-15) showed significantly the lower weed density as compared to other treatments during both the year of experimentation. Results revealed that all the doses of K-salt glyphosate, i.e. 900, 1 800 and 3 600 g ai/ha under transgenic hybrids such as Hishell and 900 M Gold hybrids of stacked corn at (T1-T6) significantly completely killed all the weeds at 30 DAS as compared to all other treatments (Table 2). At the advancement of crop stage, i.e. at 60 days after sowing, the effect of K salt of glypohsate remained same and all the transgenic treatments with different glyphosate applications registered no weed infestation (Table 3). In case of other non-transgenic treatments, weed density

Table 1 Species-wise weed density (No/m$^2$) before K-salt application at 13 days after sowing

| Treatment | *Echinochloa colona* | | *Cyperus iria* | | *Corcorus* spp. | | *Commelina benghalensis* | | *Phyllanthus niruri* | | *Physalis minima* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 |
| $T_1$- Hishell (MON 89034×NK 603) Round up @900 g/ha | 9.47 (89.18) | 4.65 (22.44) | 5.59 (30.75) | 3.35 (13.66) | 4.25 (17.56) | 0.71 (0.00) | 2.50 (5.75) | 0.71 (0.00) | 0.71 (0.00) | 2.22 (5.77) | 1.25 (1.06) | 0.71 (0.00) |
| $T_2$- Hishell (MON 89034×NK 603) Round up @1800 g/ha | 9.14 (83.04) | 5.26 (27.44) | 5.52 (29.97) | 3.88 (17.00) | 2.40 (5.26) | 0.71 (0.00) | 2.68 (6.68) | 0.71 (0.00) | 0.71 (0.00) | 1.81 (3.22) | 1.74 (2.53) | 0.71 (0.00) |
| $T_3$- Hishell (MON 89034×NK 603) Round up @3600 g/ha | 8.88 (78.35) | 4.30 (20.55) | 4.14 (16.64) | 4.37 (22.55) | 2.22 (4.43) | 0.71 (0.00) | 2.12 (3.99) | 0.71 (0.00) | 2.64 (6.47) | 1.84 (3.11) | 2.23 (4.47) | 0.71 (0.00) |
| $T_4$- 900 M Gold (MON 89034× NK 603) Round up @900 g/ha | 8.63 (73.98) | 4.45 (21.22) | 3.94 (15.02) | 3.94 (19.10) | 1.82 (2.81) | 0.71 (0.00) | 2.46 (5.55) | 0.71 (0.00) | 1.44 (1.57) | 1.07 (0.77) | 2.52 (5.85) | 0.71 (0.00) |
| $T_5$- 900 M Gold (MON 89034× NK 603) Round up @1800 g/ha | 7.30 (52.79) | 4.70 (22.89) | 4.70 (21.59) | 2.62 (7.88) | 1.86 (2.96) | 0.71 (0.00) | 1.44 (1.57) | 0.71 (0.00) | 3.02 (8.62) | 2.06 (4.10) | 1.56 (1.93) | 0.71 (0.00) |
| $T_6$- 900 M Gold (MON 89034× NK 603) Round up @3600 g/ha | 4.90 (23.51) | 5.07 (25.22) | 3.61 (12.53) | 2.44 (7.33) | 1.44 (1.57) | 0.71 (0.00) | 1.57 (1.96) | 0.71 (0.00) | 0.71 (0.00) | 0.92 (0.44) | 1.09 (0.69) | 0.74 (0.00) |
| $T_7$- Hishell Conventional (P) Atrazine @1000 g/ha and Endosulfan 35 EC @ 1250 g/ha | 3.78 (13.79) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 3.59 (12.39) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 1.87 (3.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) |
| $T_8$- Hishell Conventional (Control) | 5.92 (34.55) | 5.15 (28.55) | 4.26 (17.65) | 2.26 (6.00) | 2.12 (3.99) | 0.77 (0.11) | 0.71 (0.00) | 0.77 (0.11) | 0.71 (0.00) | 2.20 (5.00) | 2.23 (4.47) | 0.77 (0.11) |
| $T_9$- Hishell Conventional (Control) | 5.95 (34.90) | 5.85 (38.00) | 4.0 (15.66) | 2.47 (9.55) | 2.29 (4.74) | 0.87 (0.33) | 2.17 (4.21) | 0.83 (0.20) | 0.71 (0.00) | 2.16 (4.77) | 2.12 (3.99) | 0.87 (0.33) |
| $T_{10}$- 900 M Gold Conventional (P) Atrazine @1000 g/ha and Endosulfan 35 EC @ 1250 g/ha | 4.05 (15.90) | 1.03 (0.77) | 1.17 (0.87) | 1.80 (5.11) | 0.71 (0.00) | 0.71 (0.00) | 1.00 (0.5) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) |
| $T_{11}$- 900 M Gold Conventional (Control) | 6.32 (39.44) | 6.92 (52.66) | 2.80 (7.34) | 2.04 (6.33) | 2.49 (5.70) | 0.71 (0.00) | 1.65 (2.22) | 0.71 (0.00) | 0.71 (0.00) | 1.27 (1.33) | 2.39 (5.21) | 0.71 (0.00) |
| $T_{12}$- 900 M Conventional (Control) Endosulfan 35 EC @ 1250 g/ha | 6.65 (43.72) | 4.55 (20.22) | 4.18 (16.97) | 4.66 (21.44) | 3.54 (12.03) | 0.71 (0.00) | 1.25 (1.06) | 0.71 (0.00) | 1.71 (2.44) | 1.92 (4.00) | 1.25 (1.06) | 0.71 (0.00) |
| $T_{13}$- National Check conventional (P) Atrazine @1000 g/ha and Endosulfan 35 EC @ 1250 g/ha | 2.31 (4.84) | 0.88 (0.33) | 1.32 (1.24) | 1.91 (6.00) | 1.25 (1.06) | 0.71 (0.00) | 1.25 (1.06) | 0.71 (0.00) | 1.65 (2.22) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) |
| $T_{14}$- National Check conventional control | 6.78 (45.47) | 5.97 (37..10) | 4.48 (19.57) | 3.07 (11.77) | 4.73 (21.87) | 0.71 (0.00) | 2.83 (7.51) | 0.71 (0.00) | 2.45 (5.50) | 3.29 (12.77) | 2.62 (6.36) | 0.71 (0.00) |
| $T_{15}$- Local Check Conventional (P) Atrazine @1000 g/ha and Endosulfan 35 EC @ 1250 g/ha | 5.42 (28.88) | 1.00 (0.66) | 0.71 (0.00) | 1.46 (2.77) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) |
| $T_{16}$- Local Check Conventional (Control) | 7.02 (48.78) | 5.80 (35.10) | 4.63 (20.94) | 2.76 (7.44) | 2.66 (6.58) | 0.71 (0.00) | 2.40 (5.26) | 0.71 (0.00) | 1.25 (1.06) | 2.45 (7.00) | 2.47 (5.60) | 0.71 (0.00) |
| LSD (P=0.05) | 6.55 | 2.36 | 2.77 | 2.95 | NS | NS | NS | NS | NS | 1.34 | 1.35 | NS |

Figures in parenthesis are original values.

was significantly higher at both the crop stages. The total weed count was also showed significant reduction of weed population in all the transgenic hybrids as compared to other set of treatments.

*Weed dry weight and weed control efficiency (%)*

Observation on total dry weight of weeds in transgenic as well as in non-transgenic entries were recorded at 21 DAS (days after sowing) and at harvest. It is evident from the Table 4 that effect of K-salt of glyphosate applications remained for a longer period, i.e. up to harvest in all the transgenic hybrids. Results revealed that the total weed dry weight at 21 DAS and harvest was significantly negligible as there was 100% weed control in transgenic treatments as compared to non-transgenic treatments which were at par to each other except transgenic entries with regard to weed dry weight. The weed control efficiency of transgenic hybrids at all the doses was significantly much higher than all other non-transgenic treatments during 2010.

*Yield attributes and grain yield*

Number of cobs and unfilled cobs were counted at

Table 2 Effect of weed control methods on weed density (No/m$^2$) in transgenic and conventional corn hybrids (30 DAS)

| Treatment | *Echinochloa colona* | | *Cyperus iria* | | *Corcorus* sp. | | *Commelina benghalensis* | | *Phyllanthus niruri* | | *Dinebra* | | *Alternanthera sessilis* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 |
| $T_1$- Hishell (MON 89034× NK 603) Round up @900 g/ha | 1.32 (1.24) | 0.71 (0.00) | 0.88 (0.27) | 0.71 (0.00) | 1.38 (1.40) | 0.71 (0.00) | 1.44 (1.57) | 0.71 (0.00) | 2.46 (5.55) | 0.71 (0.00) | 1.38 (1.40) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) |
| $T_2$- Hishell (MON 89034× NK 603) Round up @1800 g/ha | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) |
| $T_3$- Hishell (MON 89034× NK 603) Round up @3600 g/ha | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) |
| $T_4$- 900 M Gold (MON 89034×NK 603) Round up @900 g/ha | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) |
| $T_5$- 900 M Gold (MON 89034×NK 603) Round up @1800 g/ha | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) |
| $T_6$- 900 M Gold (MON 89034×NK 603) Round up @3600 g/ha | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) |
| $T_7$- Hishell Conventional (P) Atrazine @1000 g/ha and Endosulfan 35 EC @ 1250 g/ha | 8.11 (65.27) | 1.98 (4.33) | 4.10 (16.31) | 1.79 (3.7) | 0.71 (0.00) | 0.71 (0.00) | 2.80 (7.34) | 1.09 (1.00) | 1.97 (3.38) | 1.77 (2.66) | 8.89 (78.53) | 0.71 (0.00) | 1.00 (0.5) | 0.88 (0.33) |
| $T_8$- Hishell Conventional (Control) | 5.19 (26.44) | 2.91 (8.10) | 3.49 (11.68) | 1.45 (1.66) | 1.17 (0.87) | 0.77 (0.11) | 1.47 (1.66) | 0.95 (0.44) | 8.40 (70.06) | 2.37 (5.22) | 5.65 (31.42) | 0.71 (0.00) | 2.35 (5.02) | 1.64 (1.66) |
| $T_9$- Hishell Conventional (Control) | 4.44 (19.21) | 2.95 (8.10) | 6.22 (38.19) | 1.82 (3.11) | 1.78 (2.67) | 0.87 (0.33) | 1.77 (2.63) | 1.32 (1.33) | 9.69 (93.40) | 2.38 (5.22) | 5.56 (30.41) | 0.71 (0.00) | 1.87 (3.00) | 1.85 (2.33) |
| $T_{10}$- 900 M Gold Conventional (P) Atrazine @1000 g/ha and Endosulfan 35 EC @ 1250 g/ha | 5.89 (34.19) | 2.44 (5.88) | 2.88 (7.79) | 1.80 (3.89) | 0.71 (0.00) | 0.71 (0.00) | 1.43 (1.55) | 0.77 (0.11) | 1.48 (1.69) | 1.35 (1.33) | 9.91 (97.71) | 0.71 (0.00) | 2.27 (4.65) | 1.17 (1.89) |
| $T_{11}$- 900 M Gold Conventional (Control) | 7.69 (58.64) | 2.95 (8.44) | 5.28 (27.38) | 1.49 (1.78) | 1.77 (2.63) | 0.71 (0.00) | 2.08 (3.83) | 1.00 (0.55) | 7.62 (57.56) | 2.29 (4.77) | 6.08 (36.47) | 0.95 (0.44) | 2.46 (5.55) | 1.76 (1.66) |
| $T_{12}$- 900 M Conventional (Control) Endosulfan 35 EC @ 1250 g/ha | 7.35 (53.52) | 3.04 (9.00) | 6.73 (44.79) | 2.0 (3.66) | 1.17 (0.87) | 0.83 (0.22) | 2.51 (5.80) | 1.07 (0.66) | 8.37 (69.56) | 2.43 (5.55) | 3.29 (10.32) | 0.83 (0.22) | 3.13 (9.30) | 1.95 (5.44) |

*Contd.*

Table 2 (*Concluded*)

| Treatment | *Echinochloa colona* | | *Cyperus iria* | | *Corcorus* sp. | | *Commelina benghalensis* | | *Phyllanthus niruri* | | *Dinebra* | | *Alternantherasessilis* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 |
| $T_{13}$- National Check conventional (P) Atrazine @1000 g/ha and Endosulfan 35 EC @ 1250 g/ha | 7.15 (50.62) | 2.62 (6.55) | 4.45 (19.30) | 1.58 (2.55) | 0.71 (0.00) | 0.71 (0.00) | 1.70 (2.39) | 0.77 (0.11) | 1.54 (1.87) | 1.55 (2.00) | 7.65 (58.02) | 0.71 (0.00) | 0.71 (0.00) | 1.13 (0.22) |
| $T_{14}$- National Check conventional control | 6.05 (36.10) | 2.86 (7.88) | 4.56 (20.29) | 1.69 (2.89) | 3.09 (9.05) | 0.84 (0.22) | 2.02 (3.58) | 0.91 (0.33) | 11.94 (142.06) | 2.77 (7.89) | 4.10 (16.31) | 0.71 (0.00) | 2.00 (3.5) | 1.43 (2.00) |
| $T_{15}$- Local Check Conventional (P) Atrazine @ 1000 g/ha and Endosulfan 35 EC @ 1250 g/ha | 8.64 (74.15) | 3.24 (10.33) | 4.43 (19.12) | 1.83 (2.89) | 0.71 (0.00) | 0.83 (0.22) | 0.71 (0.00) | 0.89 (0.33) | 1.00 (0.5) | 1.95 (3.33) | 13.09 (170.85) | 0.83 (0.22) | 1.55 (1.90) | 1.08 (1.00) |
| $T_{16}$- Local Check Conventional (Control) | 7.81 (60.50) | 2.82 (7.66) | 4.92 (23.71) | 1.59 (2.44) | 2.18 (4.25) | 0.71 (0.00) | 1.71 (2.42) | 1.18 (1.00) | 7.02 (48.78) | 1.58 (6.44) | 4.76 (22.16) | 0.71 (0.00) | 0.88 (0.27) | 1.20 (4.008 |
| LSD (P=0.05) | 4.01 | 0.71 | 2.05 | 1.05 | 1.74 | 0.19 | 1.49 | 0.37 | 4.12 | 0.50 | 3.88 | 0.15 | 1.50 | 0.67 |

EC- *Echinochloa colona*; CI-*Cyperus iria*, Co-*Corcorus*; Cb-*Commelina benghalensis*, Pn-*Phyllanthus niruri*, Di-*Dinebra*; As-*Alternanthera sessilis*. Figures in parenthesis are original values.



Table 3 Effect of weed control methods on species wise weed density (No/m$^2$) in transgenic and conventional corn hybrids (60 DAS)

| Treatment | *Echinochloa colona* | | *Corcorus* | | *Commelina benghalensis* | | *Dinebra* | | *Phyllanthus niruri* | | *Physalis minima* | | *Alternanthera sessilis* | | *Total weed count* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 |
| $T_1$- Hishell (MON 89034xNK 603) Round up @900 g/ha | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) |
| $T_2$- Hishell (MON 89034xNK 603) Round up @1800 g/ha | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) |
| $T_3$- Hishell (MON 89034xNK 603) Round up @3600 g/ha | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) |
| $T_4$- 900 M Gold (MON 89034xNK 603) Round up @900 g/ha | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) |
| $T_5$- 900 M Gold (MON 89034xNK 603) Round up @1800 g/ha | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) |
| $T_6$- 900 M Gold (MON 89034xNK 603) Round up @3600 g/ha | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) |

*Contd.*

Table 3 (*Concluded*)

| Treatment | *Echinochloa colona* | | *Corcorus* | | *Commelina benghalensis* | | *Dinebra* | | *Phyllanthus niruri* | | *Physalis minima* | | *Alternanthera sessilis* | | Total weed count | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 |
| $T_7$- Hishell Conventional (P) Atrazine @1000 g/ha and Endosulfan 35 EC @ 1250 g/ha | 3.28 (10.26) | 2.29 (5.33) | 0.88 (0.27) | 0.71 (0.00) | 2.17 (4.21) | 0.77 (0.11) | 5.93 (35.0) | 1.68 (2.33) | 0.71 (0.00) | 1.16 (1.11) | 1.09 (0.69) | 0.71 (0.00) | 1.60 (2.06) | 0.95 (0.44) | 7.59 (57.1) | 3.35 (11.0) |
| $T_8$- Hishell Conventional (Control) | 3.83 (14.17) | 3.14 (9.55) | 1.00 (0.50) | 0.88 (0.27) | 1.00 (0.50) | 0.83 (0.22) | 4.50 (19.75) | 0.95 (0.44) | 4.72 (21.78) | 1.84 (3.00) | 0.88 (0.27) | 1.09 (0.69) | 1.09 (0.69) | 0.90 (0.33) | 7.94 (62.54) | 3.76 (13.76) |
| $T_9$- Hishell Conventional (Control) | 3.50 (11.75) | 3.45 (11.66) | 1.67 (2.29) | 1.84 (3.00) | 1.87 (3.00) | 0.90 (0.33) | 2.93 (8.08) | 0.71 (0.00) | 6.33 (39.57) | 1.95 (3.33) | 2.54 (5.95) | 1.11 (0.73) | 1.43 (1.54) | 1.02 (0.55) | 9.63 (92.24) | 4.20 (17.54) |
| $T_{10}$- 900 M Gold Conventional (P) Atrazine @1000 g/ha and Endosulfan 35 EC @ 1250 g/ha | 3.41 (11.13) | 1.95 (3.44) | 0.71 (0.00) | 0.71 (0.00) | 2.50 (5.75) | 0.84 (0.22) | 7.62 (57.56) | 2.19 (4.33) | 0.71 (0.00) | 1.08 (0.77) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.92 (0.44) | 8.77 (76.41) | 3.29 (10.32) |
| $T_{11}$- 900 M Gold Conventional (Control) | 4.63 (20.94) | 3.10 (9.44) | 1.29 (1.16) | 0.88 (0.27) | 2.00 (3.50) | 1.03 (0.66) | 1.78 (2.67) | 0.77 (2.11) | 3.34 (10.66) | 1.61 (2.22) | 1.49 (1.72) | 1.37 (1.83) | 2.14 (4.08) | 0.95 (0.44) | 7.04 (49.06) | 3.57 (12.65) |
| $T_{12}$- 900 M Conventional (Control) Endosulfan 35 EC @ 1250 g/ha | 5.29 (27.48) | 3.23 (10.00) | 1.00 (0.50) | 1.22 (0.98) | 2.02 (3.58) | 1.06 (0.66) | 0.71 (0.00) | 0.83 (0.22) | 4.37 (18.60) | 1.66 (2.44) | 3.30 (10.39) | 2.11 (3.95) | 1.87 (3.00) | 1.70 (2.44) | 8.57 (72.94) | 4.15 (16.76) |
| $T_{13}$- National Check conventional (P) Atrazine @1000 g/ha and Endosulfan 35 EC @ 1250 g/ha | 3.60 (12.46) | 2.62 (6.77) | 2.05 (3.70) | 0.71 (0.00) | 2.45 (5.50) | 0.84 (0.22) | 5.57 (30.52) | 1.74 (2.55) | 2.54 (5.95) | 1.36 (1.55) | 0.71 (0.00) | 1.38 (1.40) | 0.71 (0.00) | 0.95 (0.44) | 8.89 (78.53) | 3.52 (12.42) |
| $T_{14}$- National Check conventional control | 3.00 (8.50) | 3.53 (12.00) | 1.68 (2.32) | 1.28 (1.21) | 1.99 (3.46) | 0.84 (0.22) | 2.02 (3.58) | 0.77 (0.11) | 6.24 (38.44) | 1.91 (3.88) | 3.02 (8.62) | 1.21 (0.96) | 1.65 (2.22) | 1.16 (0.88) | 9.06 (81.58) | 4.27 (17.88) |
| $T_{15}$- Local Check Conventional (P) Atrazine @1000 g/ha and Endosulfan 35 EC @ 1250 g/ha | 5.41 (28.77) | 3.01 (9.00) | 0.71 (0.00) | 1.09 (0.69) | 1.38 (1.40) | 0.71 (0.00) | 7.30 (52.79) | 1.57 (2.10) | 0.71 (0.00) | 1.28 (1.21) | 0.71 (0.00) | 0.92 (0.35) | 0.71 (0.00) | 0.71 (0.00) | 9.16 (83.41) | 3.57 (12.54) |
| $T_{16}$- Local Check Conventional (Control) | 5.17 (26.23) | 3.16 (9.66) | 1.180 (0.89) | - | 1.27 (1.11) | 0.84 (0.22) | 2.12 (3.99) | 0.84 (0.22) | 6.26 (38.69) | 1.89 (3.22) | 1.77 (2.63) | 1.91 (3.15) | 1.09 (0.69) | 0.97 (0.44) | 9.06 (81.58) | 3.87 (14.54) |
| LSD (P=0.05) | 1.35 | 0.77 | NS | NS | 1.49 | 0.25 | 2.89 | 0.28 | 2.00 | 0.65 | 1.64 | 0.21 | NS | 0.28 | 2.46 | 0.64 |

EC- *Echinochloa colona*; Co-*Corcorus*; Di-*Dinebra*; Pn-*Phyllanthus niruri*; Cb-*Commelina benghalensis* PM- *Physalis minima*, AS-*Alternanthera sessilis*, TWC-Total weed count. Figures in parenthesis are original values.

Table 4 Number of cobs, unfilled cobs, cob length, cob diameter, grains row/cobs and grains/row as influenced by treatments

| Treatment | No. of cobs/ plot | | Unfilled cobs/ plot | | Cob length (cm) | | Cob diameter (cm) | | Grains row/ cob | | Grains/ row | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 |
| $T_1$- Hishell (MON 89034×NK 603) Round up @900 g/ha | 84.33 | 82.00 | 0.00 | 0 | 18.21 | 18.70 | 15.04 | 14.49 | 14.33 | 13.13 | 33.83 | 36.37 |
| $T_2$- Hishell (MON 89034×NK 603) Round up @1800 g/ha | 82.00 | 80.66 | 0.00 | 0 | 18.27 | 19.17 | 13.51 | 14.58 | 13.97 | 13.07 | 33.33 | 36.27 |
| $T_3$- Hishell (MON 89034×NK 603) Round up @3600 g/ha | 85.33 | 80.66 | 0.00 | 0 | 17.23 | 19.64 | 13.43 | 14.39 | 13.93 | 13.13 | 35.00 | 36.80 |
| $T_4$- 900 M Gold (MON 89034× NK 603) Round up @900 g/ha | 81.33 | 81.00 | 0.00 | 0 | 14.75 | 16.88 | 14.66 | 16.48 | 14.67 | 14.60 | 30.57 | 35.43 |
| $T_5$- 900 M Gold (MON 89034× NK 603) Round up @1800 g/ha | 80.33 | 81.33 | 0.00 | 0 | 14.58 | 16.62 | 14.31 | 16.36 | 14.87 | 14.67 | 28.87 | 34.80 |
| $T_6$- 900 M Gold (MON 89034× NK 603) Round up @3600 g/ha | 81.70 | 82.33 | 0.00 | 0 | 14.99 | 16.63 | 14.69 | 15.68 | 14.93 | 14.80 | 31.40 | 32.47 |
| $T_7$- Hishell Conventional (P) Atrazine @1000 g/ha and Endosulfan 35 EC @ 1250 g/ha | 79.00 | 79.00 | 0.67 | 1.66 | 15.74 | 16.42 | 13.39 | 14.23 | 14.20 | 13.67 | 31.43 | 34.67 |
| $T_8$- Hishell Conventional (Control) | 68.00 | 74.66 | 0.33 | 4.33 | 13.97 | 14.15 | 12.62 | 12.82 | 13.90 | 12.87 | 28.10 | 29.93 |
| $T_9$- Hishell Conventional (Control) | 76.70 | 69.33 | 2.67 | 5.67 | 14.89 | 13.86 | 13.22 | 12.99 | 13.53 | 12.73 | 33.10 | 27.63 |
| $T_{10}$- 900 M Gold Conventional (P) Atrazine @1000 g/ha and Endosulfan 35 EC @ 1250 g/ha | 80.33 | 72.00 | 1.33 | 1.67 | 15.47 | 15.06 | 13.46 | 14.63 | 15.33 | 13.87 | 30.10 | 31.10 |
| $T_{11}$- 900 M Gold Conventional (Control) | 70.00 | 7633 | 2.00 | 5.33 | 13.77 | 16.23 | 13.93 | 14.95 | 14.50 | 14.00 | 28.10 | 33.67 |
| $T_{12}$- 900 M Conventional (Control) Endosulfan 35 EC @ 1250 g/ha | 70.70 | 59.33 | 2.33 | 4.33 | 13.32 | 13.62 | 14.05 | 14.31 | 14.13 | 12.93 | 28.13 | 28.23 |
| $T_{13}$- National Check conventional (P) Atrazine @1000 g/ha and Endosulfan 35 EC @ 1250 g/ha | 79.00 | 77.00 | 3.00 | 5.67 | 14.64 | 17.39 | 13.96 | 16.14 | 13.03 | 13.33 | 27.47 | 32.47 |
| $T_{14}$- National Check conventional control | 62.00 | 59.66 | 3.00 | 6.67 | 14.01 | 13.69 | 13.78 | 14.85 | 12.87 | 12.37 | 26.80 | 22.10 |
| $T_{15}$- Local Check Conventional (P) Atrazine @1000 g/ha and Endosulfan 35 EC @ 1250 g/ha | 76.00 | 71.66 | 4.00 | 3.00 | 14.73 | 16.42 | 12.73 | 13.67 | 13.23 | 12.40 | 28.00 | 32.80 |
| $T_{16}$- Local Check Conventional (Control) | 41.33 | 25.33 | 5.00 | 7.00 | 13.39 | 13.28 | 11.06 | 12.87 | 11.23 | 12.03 | 23.83 | 26.13 |
| LSD (P=0.05) | 15.08 | 11.65 | 1.52 | 2.14 | 2.30 | 2.31 | 1.49 | 1.33 | 1.37 | 0.88 | 4.40 | 6.15 |

harvest clearly showed that number of cobs, lowest unfilled cobs, cob length and grains per row were significantly higher in transgenic corn hybrid of Hishell and 900M Gold as compared to non-transgenic treatments. Significantly higher number of unfilled cobs was recorded in National and Local Check conventional control treatments. Higher values of cob length were observed in transgenic corn hybrids followed by conventional treatments. National check conventional control (T-14), local check conventional (P) Atrazine @1 000 g/ha and Endosulfan 35 EC @ 1 250 g/ha (T-15) and local check conventional (control) (T-16) treatments showed lowest grains/cob. In case of grains/row, Hishell at all the rates (T1-T3) was significantly higher than the other treatments except Hishell Conventional (Control)T8, Hishell Conventional (Control, with no weeding but only insect management) T9, 900 M Conventional (Control) Endosulfan 35 EC @ 1 250 g/ha (T12), National check conventional control (T-14), and local check conventional (control) (T-16) which were at par. Hishell at the all rates were found better as compared to 900 M Gold with regard to grains row per cob during both the years.

Hishell and 900 M Gold treated with roundup @ 900,

Table 5 Effect of weed control methods on total dry weight of weeds (g /m$^2$) and grain yield (tonnes/ha) in transgenic and conventional corn hybrids

| Treatment | Weed dry weight (21 DAS) | | Weed dry weight (At harvest) | | Yield (t/ha) | |
|---|---|---|---|---|---|---|
| | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 |
| $T_1$- Hishell (MON 89034×NK 603) Round up @900 g/ha | 0.71(0.0) | 0.71(0.00) | 0.71(0.0) | 0.71(0.00) | 8.06 | 9.74 |
| $T_2$- Hishell (MON 89034×NK 603) Round up @1800 g/ha | 0.71(0.0) | 0.71(0.00) | 0.71(0.0) | 0.71(0.00) | 7.27 | 9.45 |
| $T_3$- Hishell (MON 89034×NK 603) Round up @3600 g/ha | 0.71(0.0) | 0.71(0.00) | 0.71(0.0) | 0.71(0.00) | 7.87 | 9.67 |
| $T_4$- 900 M Gold (MON 89034×NK 603) Round up @900 g/ha | 0.71(0.0) | 0.71(0.00) | 0.71(0.0) | 0.71(0.00) | 6.56 | 9.20 |
| $T_5$- 900 M Gold (MON 89034×NK 603) Round up @1800 g/ha | 0.71(0.0) | 0.71(0.00) | 0.71(0.0) | 0.71(0.00) | 6.70 | 10.09 |
| $T_6$- 900 M Gold (MON 89034×NK 603) Round up @3600 g/ha | 0.71(0.0) | 0.71(0.00) | 0.71(0.0) | 0.71(0.00) | 6.86 | 6.72 |
| $T_7$- Hishell Conventional (P) Atrazine @ 1000 g/ha and Endosulfan 35 EC @1250 g/ha | 6.94(47.7) | 6.58 (43.25) | 5.54(30.2) | 9.2786.97 | 5.80 | 6.37 |
| $T_8$- Hishell Conventional (Control) | 9.21(84.2) | 8.44(72.87) | 7.46(55.2) | 10.98(124.84) | 3.49 | 2.04 |
| $T_9$- Hishell Conventional (Control) | 7.71(59.0) | 8.05(65.04) | 6.35(39.8) | 10.99(122.34) | 5.07 | 3.01 |
| $T_{10}$- 900 M Gold Conventional (P) Atrazine @1000 g/ha and Endosulfan 35 EC @ 1250 g/ha | 6.45(41.1) | 8.53(76.28) | 6.15(37.3) | 11.12(131.90) | 6.04 | 6.97 |
| $T_{11}$- 900 M Gold Conventional (Control) | 9.97(98.8) | 8.88(81.46) | 8.38(69.7) | 12.62(168.48) | 3.81 | 3.00 |
| $T_{12}$- 900 M Conventional (Control) Endosulfan 35 EC @ 1250 g/ha | 10.08(101.1) | 7.70(66.74) | 8.07(64.6) | 10.99(134.18) | 4.82 | 4.59 |
| $T_{13}$- National Check conventional (P) Atrazine @1000 g/ha and Endosulfan 35 EC @ 1250 g/ha | 7.26(52.1) | 6.17(37.64) | 4.65(21.1) | 8.90(79.68) | 5.00 | 5.65 |
| $T_{14}$- National Check conventional control | 10.75(115.0) | 7.72(64.00) | 8.60(73.5) | 10.61(117.26) | 3.39 | 1.51 |
| $T_{15}$- Local Check Conventional (P) Atrazine @1000 g/ha and Endosulfan 35 EC @ 1250 g/ha | 7.53(56.2) | 6.70(45.89) | 4.81(22.6) | 9.58(91.84) | 2.64 | 3.91 |
| $T_{16}$- Local Check Conventional (Control) | 10.86(117.5) | 10.30(106.58) | 8.72(75.6) | 14.46(209.61) | 1.33 | 2.15 |
| LSD (P=0.05) | 2.58 | 2.18 | 2.43 | 2.87 | 1.81 | 2.89 |

DAS: Days after sowing.

1 800 and 3 600 g ai/ha yielded significantly higher grain yield compared to remaining other treatments. T7 and T10 were at par to 900 M Gold at 3 600 g/ha transgenic but were significantly inferior to Hishell round up at all the rates (Table 4). Hishell and 900M Gold stack corn roundup at all the rates stood at par to each other. Amongst transgenic hybrids, Hishell at 1 800 g ai/ha performed well and yielded significantly the highest grain yield of stacked corn (Kannan and Chinnagounder 2014 and Anonymous 2011). Data in the Table 5 indicated that the yield under transgenic hybrids was significantly higher as compared to non-transgenic treatments and was 3-4 fold more than the national and local checks. In case of corn hybrid, yield of 900 M Gold decreased as the post emergence application of glyphosate was enhanced from 1 800 to 3 600 g/ha, i.e. from 10.02 to 6.72 tonnes/ha, respectively. While in case of Hishell, yield levels remained constant. This could be the achieved control of weeds with non-selective, translocated herbicide, provided complete control of weeds and favourable crop growth environment at the establishment stage of the crop itself by minimizing the perennial and annual weeds and increased the seed yield (Tharp *et al*, 1999). This might be due to the fact that, the perennial weeds like *Cyperus* spp*,* andother troublesome weeds were effectively controlled and might increase the corn yield levels may be due to better light utilization of narrow row zone and faster canopy closure (Murphy *et al*. 1996).

Results revealed that lesser weed dry weight and higher weed control efficiency was achieved using post emergence application of glyphosate at all the rates in in Hishell and 900M Gold transgenic hybrids as compared to other treatments at 14 and 21 DAT which kept and maintained season-long control of weeds and consequently increased grain yield of Hishell and 900 M Gold transgenic corn

hybrids (grain yield ranged between 9.45 to 10.02 tonnes/ha), is approximately three to four times higher than the average yield of corn per ha, i.e. 2.30 tonnes/ha. The results confirmed the role of transgenic corn under K-salt application of glyphosate in increasing the yield significantly.

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