Evaluate the efficiency of Bonanza weedicide to control *Cuscuta pentagona* on eggplant

Bashar Kadhim H. Al-Gburi* and Akeel Emad Mohammed

1Department of Plant Protection, Faculty of Agriculture, University of Kufa, Najaf, Iraq.

Email: bushark.algbori@uokufa.edu.iq

Abstract. Field dodder (*Cuscuta pentagona*) is a predominant plan parasite on Solanaceous vegetables in Iraq. Series of field experiments were carried out in Najaf province during 2018 season to evaluate the efficiency of Bonanza to control *C. pentagona* parasitizing on eggplant. Results highlighted that there were significant differences in all studied indicators in comparison with control treatment. Bonanza treatment was greater in term of leaves number, surface area, plant height, dry weight of root and shoot, less time to mature the first fruit and increasing the production of fruits for each plant. Leave contains of carbohydrates, mineral elements, salicylic acid, chlorophyll, total phenols and plant hormones (IAA, GA3) were increased compared to control treatment. Fruit contains of Ascorbic acid and total soluble solids were also increased. Bonanza weedicide was controlled *C. pentagona* on treated plants as well as increased early and total field productivity respectively (8.016, 67.68 t/ha-1) in comparison with control (6.690, 40.80 t/ha-1). GC-MS analyses showed that there is no weedicide residues on fruits treated with Bonanza after ten days.

1. Introduction

Eggplant (*Solanum melongena* L.) is the most cultivated vegetable in Iraq that belonging to Solanaceae which has more than 98 genera and 2700 species [1].Solanaceous vegetables particularly eggplant are rich source of protein (14.34%), oil (2.82%), fibres (63.87%), carbohydrates, and vitamins A, B1, B2 and C. It also contains many nutrients such as calcium, phosphor and iron which consider essential for human feed [2]. In Iraq, the area that is grown by Solanaceae plants has expanded to 25705 dunum in 2018 with average of yield up to 4061.5 kg/dunum [3].However, cultivating eggplant faces many challenges including weeds, pests and plant diseases that affected the quality and quantity of plants [4].

*C. pentagona* is belonging to Convolvulaceae and considering as a predominant weed that attacked eggplant. Dodder has been classified as a dangerous weed [5], particularly in Iraq where some studies reported the severity of *Cuscuta* spp.Al-Gbur et al., [6] mentioned that dodder present at different sites assessed in the middle of Iraq, with the site incidence ranging for 50.5% to 88.7% infected by *Cuscuta campestris* and *C. pentagona* infected about 76.2%. *C. pentagona* has no root and leaves, chlorophyll-less plant parasite depends entirely on plant host for reproduction and survive [7; 8]. Parasitism needs to configure haustorium to transfer mRNA between filament – tube of *C. pentagona* and wood or bark tissues of the host to complete connection and identification process [9].
Configuring many of haustorium may lead to host collapse as a result of absorption of many nutrients and photosynthesis products which cause poor quality and quantity of eggplant [10; 11].

There are some management options for *C. pentagona* but some are limited and often inadequate control which made the chemical treatment as a first strategy to reduce yield losses in eggplant and another Solanaceae. For instance, Eizenberg et al., [12] found that sulfosulfuron was affected to control *C. pentagona* on tomato. However, studies focusing in selective control to *Cuscuta* spp. on eggplant are limited. Thus, the objective of current study is to evaluate the efficiency of Bonanza as chemical control to manage *C. pentagona* without affecting the plant host.

2. Material and methods
2.1. Diagnosis of *C. pentagona*

*C. pentagona* samples (flowers) were transferred to the purpose of performing the phenotypic diagnosis by anatomical microscope according to the classification key suggested by Spaulding, [13].

2.2. Experimental procedure and treatments

Experiments were conducted during March 2018 in a private farm in Kufa, located 26 km north of Najaf province. Random samples of field soil were taken before planting and after planting. The process of preparing the 50 m² field was carried out by removing the plant residues then soil was treated with a fungicide, and nematicide. The field was irrigated by drip irrigation system two days before planting the transplants to humidify the soil. Transplants were planted in the experimental units on each side of the furrow, at a distance of 30 cm between plants and alternately, so that planting 8 transplant per experimental unit (2.5 m²). The compound fertilizer (under plant lines) was added at rate of 100 g per experimental unit, plants were fertilized before flowering with 60 g per experimental unit of a mixture of DAP 200 kg. ha⁻¹ and Urea 400 kg ha⁻¹, and during fruits setting 20 g of Urea per experimental unit were added. To reduce insects damages a Pheromone traps were distributed in the field.

Eggplant cultivar (Barcelona hybrid) produced by Semillas Fitó of Spain in 2014 was used in this study. Treatments were arranged in Randomized Complete Block Design (RCBD). Thus, the numbers of treatments were 2, in each of six replicates and the total number of experimental units were 12. The treatments were as follows:

1) Foliar spray by Bonanza herbicide (C₁₆H₁₈N₆O₇S₂), the concentration was100 g ai ha⁻¹ as recommended with Tween 20 (surfactant) at a concentration of 0.01%. (infection by *C. pentagona* with treatment).
2) Control (infection by *C. pentagona* non-treated).

After two months of planting, the infection was implemented by a fresh weight of five grams of *C. pentagona* filaments on eggplant. Two weeks after infection the development of the treatments were applied, and foliar spray of Bonanza treatment was performed.

2.3. Data collection (Vegetative growth and chemical indicators).

Three plants were randomly selected from each experimental unit for each treatment and marked to measure their following vegetative indices (after third fruit harvest):

1) Number of leaves (leaf.plant⁻¹): The number of leaves per plant at harvest was calculated.
2) Leaf area (dsm².plant⁻¹): The leaf area calculation according to [14].
3) % Fruit set: Fruit set calculated from the following equation:
4) % Fruit set = (Number of flowers set / Total number of flowers) × 100
5) Estimation of total soluble carbohydrates (mg.g⁻¹): According to the method of [15].
6) % Nitrogen: Nitrogen was estimated using the Kjeldahl apparatus, according to [16].
7) % Phosphorus: Phosphorus was estimated using the Olsen method, according to [16].
8) % Potassium: Potassium was estimated using the Flame photometer device, according to [17].
9) % Calcium: Calcium was estimated using the Flame photometer device, according to [18].
10) Total chlorophyll (mg 100g\(^{-1}\)): Total chlorophyll was estimated according to [19].
11) % Protein: Protein percentage was calculated using Kjeldahl method according to [20].
12) Free hormones (µM): Free plant hormones including Indole-3-acetic acid (IAA), Gibberellic acid
(GA\(_3\)), and Abscisic acid (ABA) were determined according to [21].
13) Total phenolic compound (mg ml\(^{-1}\)): Total phenol analysis was performed using Folin-Ciocalteu
reagent, according to [22].
14) Salicylic acid (µg ml\(^{-1}\)): Salicylic acid was estimated using the HPLC model (SYKAM,
Germany), according to [23].
15) Ascorbic acid (mg 100 mg\(^{-1}\)): Ascorbic acid was estimated using the 2,6- Dichlorophenol
indophenol pigment, according to [24].
16) % Total Soluble Solids (TSS): Total Soluble Solids was estimated using Hand refractometer
device, according to [25].
17) Yield indicators: The harvest was carried out every 4 - 7 days, start in 30/5/2018 and the final
harvest was in 10/9/2018.
18) Days to pick first fruit (day): This was recorded by the time limited from the date of transplanting
to the first picking date of fruit.
19) Number of fruits (fruit plant\(^{-1}\)): This was calculated by dividing the total number of fruits of
experimental unit on number of plants.
20) Average of weight of fruit (g): This was calculated by dividing the total weight of fruits per
experimental unit on the number of fruits per experimental unit and then the mean was calculated.
21) Productivity of plant (kg plant\(^{-1}\)). This was calculated by dividing the total fruit yield of each
experimental unit on the number of plants and then the mean was calculated.
22) Early yield (ton ha\(^{-1}\)): The amount of early yield was calculated by the total of first three picks per
experimental unit, and then according to the hectare was estimated.
23) Total yield (ton ha\(^{-1}\)): The amount of total yield was calculated by the total yield of picks per
experimental unit, then according to the hectare was estimated, using to the following equation.
24) Total yield (ton ha\(^{-1}\)) = the yield of experimental unit (ton) × 10000 m\(^2\) ha\(^{-1}\) the area of
experimental unit (m\(^2\))
25) Plant height (cm): It was measured for the main stem from soil surface to apical of the longest
productive branch by measuring tape.
26) Dry weight of vegetative part and root part (g plant\(^{-1}\)) was estimated using the oven device,
according to [16] and then the mean was calculated.
27) Infection ratio: infection ratio was calculated, according to [26].
28) Detection of herbicide residues
29) After ten days of herbicide foliar spray (Bonanza), three fruits of eggplant were taken randomly
and washed individually under running tap water to remove any traces of dirt. The samples were
dried at 70°C for 2 days in an oven. They were then macerated to powder form with a mixer
grinder, then the fruits powder was mixed at both to form inclusive sample of Bonanza treatment.
The herbicide residue was measured using standard (Herbicide, Bonanza), then sample was tested
by GC-MS device according to method of [27].

2.4. Statistical analysis
Data were analyzed by Statistical Analysis Software “SAS/STAT” [28]. The means were compared
according to Least Significant Difference (L.S.D) at 0.05 probability level.
3. Results and Discussion

There were significant differences in all studied characteristics in comparison with control treatment (Table 1). Growth indicators were greater in Bonanza treatment that increased leaves number, surface area, plant height, dry weight of root and shoot. Less time to mature the first fruit was also recorded (70.6 day) when Bonanza weedicide applied in comparison with (79.3 day) in the control and the production of fruits for each plant increased. It was also increased early and to total field productivity respectively (8.016, 67.68 t/ha⁻¹) in comparison with control (6.690, 40.80 t/ha⁻¹).

Results showed that the chemical contains of Leaves [carbohydrates, mineral elements, salicylic acid, chlorophyll, total phenols and plant hormones (IAA, AG₃)] were increased compared to control treatment (Table 1). Leaves contains of Abscisic acid (ABA) hormone in the control treatment was higher (344.70µM) compared to Bonanza treatment (225.40µM). The percentage of infected eggplant was 0.0% in weedicide treatment, while it reached 93.84% in the non-treated plants (control treatment). GC-MS analyses showed that there were two component actives of Bonanza {2-Amino-4,6-dimethoxypyrimidine and 2-Pyridinecarbo-xamid, N-(2'-acetylphenyl)} (Table 2). The data of eggplant fruit analyzed by GC-MS after ten days of treatment with the weedicide showed in (Table 3).

| Treatments | Number of leaves (leaf.plant⁻¹) | Leaf area (dsm².plant⁻¹) | Dry weight of vegetative (g.plant⁻¹) | Dry root weight (g.plant⁻¹) | Plant height (cm) | Fruit set % |
|------------|--------------------------------|--------------------------|-------------------------------------|-----------------------------|------------------|-------------|
| Bonanza    | 41.0 *                         | 62.4*                    | 61.00 *                             | 58.28 *                    | 45.3 *           | 92.66 *     |
| Control    | 37.6                           | 49.80                    | 42.66                               | 31.68                       | 37.3             | 80.22       |
| LSD (0.05) | 0.796                          | 2.446                    | 2.348                               | 5.066                       | 1.229            | 0.925       |

| Treatments  | Days to pick first fruit (day) | Number of Fruit (fruit.plant⁻¹) | Weight of fruit (g) | Productivity of plant (Kg.plant⁻¹) | Early yield (ton.ha⁻¹) | Total yield (ton.ha⁻¹) |
|-------------|--------------------------------|---------------------------------|---------------------|-------------------------------------|------------------------|------------------------|
| Bonanza     | 70.6 *                         | 10.30 *                         | 139.75 *            | 1.41 *                              | 8.016 *                | 67.68 *                |
| Control     | 79.3                           | 8.25                            | 131.26              | 0.85                                | 6.690                  | 40.80                  |
| LSD (0.05)  | 1.276                          | 2.227                           | 2.06                | 0.196                               | 0.689                  | 0.635                  |

| Treatments | N% | P% | K% | Ca % | Total carbohydrates (mg.g⁻¹) | Total chlorophyll (mg.100g⁻¹) |
|------------|----|----|----|------|------------------------------|-----------------------------|
| Bonanza    | 0.97 * | 0.64 * | 1.38 * | 1.28 * | 53.0 *                     | 72.80 *                     |
| Control    | 0.52 * | 0.41 | 0.91 | 1.024 | 32.70 | 40.60                     |
| LSD (0.05) | 0.078 | 0.018 | 0.1114 | 0.136 | 4.214 | 11.082                     |

| Treatments | IAA (µM) | ABA (µM) | GA₃ (µM) | Protein % | Total Phenols (mg.g⁻¹) | Salicylic acid (µg.ml⁻¹) |
|------------|----------|----------|----------|------------|------------------------|--------------------------|
| Bonanza    | 0.683 * | 225.40   | 8.12 *   | 6.06 *     | 8.71 *                 | 170.30 *                 |
| Control    | 0.28 | 344.70 * | 4.20 | 3.25 | 6.20 | 59.70 |
| LSD (0.05) | 0.0153 | 30.885 | 0.618 | 0.640 | 0.890 | 12.94 |

| Treatments | TSS % | Ascorbic acid (mg.100g⁻¹) | Infection ratio% |
|------------|-------|---------------------------|------------------|
| Bonanza    | 7.004 * | 18.80 *            | 0.00             |
| Control    | 5.08 | 9.70 | 93.84 * |
| LSD (0.05) | 0.231 | 0.650 | 19.48 |

(*) Treatment had significant mean difference compared to other treatment.

Table 1. Effect of Bonanza foliar on growth, productivity and biochemical content of eggplant.
Table 2. GC-MS analyzed of Bonanza herbicide, the compound highlighted is a component actives of Bonanza.

| Peak | R.Time | Area   | Area% | Name of Compound                        |
|------|--------|--------|-------|----------------------------------------|
| 1    | 10.806 | 2773611| 11.97 | 2-Amino-4,6-dimethoxypyrimidine         |
| 2    | 12.779 | 915267 | 3.95  | Dodecane, 1-chloro-                     |
| 3    | 12.846 | 8263428| 35.65 | 1-Dodecanol                             |
| 4    | 14.304 | 608846 | 2.63  | Diethyl Phthalate                       |
| 5    | 15.370 | 3531875| 15.24 | 1-Tetradecanol                          |
| 6    | 18.784 | 2087231| 9.00  | Pentadecanoic acid                     |
| 7    | 20.765 | 271696 | 1.17  | 9,12-Octadecadienoic acid (Z,Z)-        |
| 8    | 20.847 | 2130694| 9.19  | 2-Pyridinecarboxamide, N-(2’-acetylphenyl)- |
| 9    | 21.096 | 803833 | 3.47  | Octadecanoic acid                      |
| 10   | 24.979 | 1792693| 7.73  | Benzenamine, N-methyl-2,4-dinitro-      |
| Total|        | 23179174| 100.00|                                         |

Table 3. GC-MS analyzed of eggplant (treatment: Bonanza).

| Peak | R.Time | Area   | Area% | Name of Compound                        |
|------|--------|--------|-------|----------------------------------------|
| 1    | 3.113  | 179296 | 5.40  | Nickel tetracarbonyl                   |
| 2    | 7.889  | 254385 | 7.66  | 4H-Pyr-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl- |
| 3    | 13.865 | 94069  | 2.83  | Tetradecyltrifluoroacetate             |
| 4    | 14.191 | 602020 | 18.13 | (1R,3R,4R,5R)-(-)-Quinic acid          |
| 5    | 15.604 | 152209 | 4.58  | Hydroquinone, acetate                  |
| 6    | 17.838 | 547941 | 16.50 | 1-(+)-Ascorbic acid 2,6-dihexadecanoate |
| 7    | 19.834 | 393483 | 11.85 | 9,12-Octadecadienoic acid (Z,Z)-       |
| 8    | 19.898 | 667434 | 20.10 | 6-Octadecenoic acid, (Z)-              |
| 9    | 20.159 | 298117 | 8.98  | Octadecanoic acid                      |
| 10   | 28.767 | 130967 | 3.94  | Stigmasterol                           |
| Total|        | 3319921| 100.00|                                         |

This study highlighted the ability of Bonanza herbicide to control C. pentagona that infect eggplant. Effects of weed on plants are completion on soil nutrition, sun light, water and CO₂. However, C. pentagona causes more damages to plant host by configuring haustorium that absorbed high amount of calcium, potassium, phosphor, nitrogen and organic acids from wood or bark tissues [29]. In current study, the parasitism of C. pentagona on eggplant caused negative effect and decreased the percentage of chlorophyll, carbohydrates, proteins and vitamins. In addition, it decreased the concentration of total soluble solids and plant growth hormones and increased Abscisic acid (ABA), this corresponds to previous studies by Press et al., [30] and [31]. High infection level by C. pentagona on eggplant made the chemical defense of plant very weak which leaded to decrease plant growth and affected the morphological of the host [32]. These chemical and vegetative changes caused physiological stress that decreased the productivity of eggplant clearly.
Spraying of Bonanza played significant role to control *C. pentagona* infection by enhancing the producing of Phytoalxin and preventing the transfer of photosynthesis products to plant parasite from the host [34]. The use of herbicide affected the parasitizing of *C. pentagona* and promoted plant growth hormones also increased the productivity [35]. Interaction of Bonanza chemical structure with some compounds of eggplant may produce other compounds that increased salicylic acid and total phenols which led to enhance the induce systematic resistance (ISR) against *C. pentagona* [36]. GC-MS analyses showed that there is no weedicide residues on eggplant fruits treated with Bonanza after ten days. This may due to biodegrade these residues or combines with other compounds in eggplant and made non-toxic materials [37].

4. Conclusion
Bonanza herbicide is an efficient control to *C. pentagona* that infect eggplant. Treated plants are significantly better in term of growth indictors, quality and quantity of eggplant fruits. This study also indicates the fast biodegrade of Bonanza residues on treated plants and grower can spray the herbicide safely.

5. Acknowledgements
Authors are grateful to University of Kufa, Faculty of Agriculture in Iraq for using the faculty facilities to complete this study. No author has any conflict of interest to declare.

References

[1] Olmstead RG and Boh L 2007 A Summary of molecular systematic research in Solanaceae: 1982-2006. *Actahort.* **745** 255-268.

[2] Hussain J et al 2010 Proximate and essential nutrients evaluation of selected vegetables species from Kohat region *Pakis. J.Botan.* **42** 2847-2855.

[3] CSO 2018 Central Statistical Organization Iraq. http://cosit.gov.iq/ar/agri-stat/veg-prod.

[4] Medakker A and Vijayaraghavan V 2007 Successful commercialization of insect-resistant eggplant by a public–private partnership: reaching and benefiting resource-poor farmers in Intellectual Property Management in Health and Agricultural Innovation: A Handbook of Best Practices. U.S.A. (USA: Available online at: www.ipHandbook.org).

[5] Weed Seeds Order 2016 The Ministry of Agriculture and Agri-Food, Canada, Ottawa, May 6. Available at: http://laws-lois.justice.gc.ca/.

[6] Al-Gburi BK et al 2018 Morphological and molecular diagnosis of Cuscutasp parasitizing Solanaceae plants in the middle of Iraqi provinces. *J. Rese. Eco.* **6** 2415-2433.

[7] Van der Kooij TA et al 2000 Molecular, functional and ultrastructuralcharacterisation of plastids from six species of the parasitic flowering plant genus Cuscuta. *Planta* **210** 701–707.

[8] Tešitel J 2016 Functional biology of parasitic plants: A review. *Plant Eco. Evo.* **149** 5-20.

[9] Kim G and Westwood JH 2015 Macromolecule exchange in Cuscuta–host plant interactions. *Curr Opinion. Plant Bio.* **26** 20-25.

[10] Birschwilks M et al 2007 Arabidopsis thaliana is a susceptible host plant for the holoparasite *Cuscuta* spp. *Planta* **226** 1231-1241.

[11] Runyon JB et al 2008 Parasitism by Cuscuta pentagona attenuates host plant defenses against insect herbivores. *J. Plant Physio.* **146** 987-95.

[12] Eizenberg H et al 2003 The potential of sulfosulfuron to control troublesome weeds in tomato. *Weed Techno.* **17** 133-137.

[13] Spaulding DD 2013 Key to the dodder (Cuscuta, Convolvulaceae) of Alabama and Adjacent States. *Phytoneuron* **74** 1-15.
[14] Watson DJ and Watson AM 1953 Comparative physiological studies on the growth of field crops III. Effects of infraction with (Beet yellow). *Ann. Applied Bio.* 40 1-18.
[15] Dubois MK et al 1956 Colorimetric method for determination of sugars and related substances. *Anal. Chem.* 28 350-365.
[16] Al-Sahaf FH 1989b *Applied plant nutrition* (Baghdad, Iraq: Bait Alhakma).
[17] Horneck DA and Hanson D 1998 *Determination of potassium and sodium by flame emission spectrophotometry* (Florida, USA : CRC Press).
[18] Brogan JC 1960 Flame-photometric determination of calcium in plants. *J. Sci. Fo. Agri.* 11 446-449.
[19] Goodwin TW 1976 *Chemistry and biochemistry of plant pigments* 2nd Ed (New York, USA: Academic Press).
[20] AOAC 2005 *Official Methods of Analysis of AOAC International*, 18th Ed Gaithersburg, *M.D.* 210 1.11.
[21] Ergun N et al 2002 Auxin (Indole-3-acetic acid), Gibberellic acid (GA3), Abscisic Acid (ABA) and Cytokinin (Zeatin) Production by Some Species of Mosses and Lichens. *Turk. J. Botan.* 26 13-18.
[22] Slinkard K and Singleton VL 1997 Total phenol analyses; Automatic and caparison with manual methods. *Amer. J. Enolog. Viticult.* 28 49-55.
[23] Bhuyian HU et al 2015 Development and validation of method for determination of Clobetasol Propionate and Salicylic acid from pharmaceutical dosage form by HPLC. *Brit. J. Pharm. Res.* 7 375-385.
[24] AOAC 2002 *Official Methods of Analysis of AOAC International*, Washington, USA, *Secs.* 967.21.
[25] AOAC 1995 *Official Methods of Analysis of AOAC International*, Washington, USA *Secs.* 942.15.
[26] Yu H et al 2011 Cuscutaaustralis restricts three exotic invasive plants and benefits native species. *Bio.Invas.* 13 747-756.
[27] Hanuš L O et al 2006 Comparative study of volatile compounds in the fresh fruits of Mandragoraautumnalis. *Acta. Chrom.* 17 151-160.
[28] Gomez K A and Gomez A A 1984 *Statistical procedures for Agriculture Research Second Ed.* (New York, USA: John Wiley and Sons - Scientific Publishers).
[29] SaričKrsmanović M et al 2013a *Effect of Cuscutacampestris on the nitrogen, phosphorus and potassium content in alfalfa and sugar beet.* (Belgrade, Serbia: the Serbian Plant Physiology Society).
[30] Press M C et al 1999 *Parasitic plants: physiological and ecological interactions with their hosts. Physiological plant ecology* (York, UK: the 39th Symposium of the British Ecological Society).
[31] Sarič-Krsmanović M et al 2012 *Morfološke, anatomske i fiziološkepromenenalucerki i šecernojirepinapadnutimvilinomkosicom (CuscutacampestrisYunck.)* (Beograd, Srbija: DruštvozazaštitibiljaSrbije).
[32] Matković A et al 2012 *Uthicajvilinekosice (CuscutacampestrisYunck.) naanatomskugradustablalucerke (Medicagosativa L.) u uslovimasi i bezprimeneherbicida* (Beograd, Srbija: DruštvozazaštitibiljaSrbije).
[33] Alakonya A et al 2012 *Interspecific RNA Interference of shoot meristemless-like disrupts Cuscuta pentagona Plant Parasitism* (New York, USA: American Society of Plant Biologists).

[34] Das SK 2013 Mode of action of pesticides and the novel trends-A critical review. *Inter. Rese. J. Agri.Scie Soil Scie.* 3 393-401.

[35] Goldwasser Y et al 2012a Control of field dodder (*Cuscuta campestris*) parasitizing tomato with ALS inhibiting herbicides. *Weed Techno.* 26 740-746.

[36] Goldwasser Y et al 2012b Detection of resistant chickpea (*Cicer arietinum*) genotypes to Cuscutacampestris *Weed Rese.* 52 122–130.

[37] Senseman S A 2007 *Herbicide Handbook. 9th Ed.* (Champaign, Illinois, USA: Weed Science Society of America).