SUST
Journal of Agricultural and Veterinary Sciences
Journal homepage:
http:// journals.sustech.edu

Design and Field Evaluation of a New Mechanism of Hydraulic Sprayer Boom for Weeds Control in Irrigation Canals

Abdalla Noureldin Osman Kheiry[1]; Mysara Ahmed Mohamed[1]

1-Department of Agricultural Machinery- College of Aricultural Studies-Sudan University of science and Technology- Khartoum- Sudan). Email: abdallakheiry@gmail.com

Received: October 2021 **Accepted: December 2021**

Abstract
The standard of maintenance of irrigation canals and drainage is poor in many irrigation systems throughout the world Inferior management of those weeds growing in the canal, aquatic weeds leads to a number of economic, social and environmental problems. With the wide range of chemicals available it is most important that the appropriate herbicide be used for any particular weed; currently, most of the machines that used in the spraying are operated on flat surfaces and open fields and cannot be used to spray pesticide solutions inside the irrigation canals. Therefore, the present work aimed to design and manufactured a new combination boom mechanism for weeds control in irrigation canal. The new-designed boom mechanism included horizontal boom, vertical boom, flexible connection, lateral boom and supported boom. With the combination of the theories and methods of spray distribution uniformity, effective spray droplets coverage, the spray scale of combination boom in the vertical pipe line was determined as 3000mm. The evaluation process for the new design was performed by carrying out field experiment at the main irrigation canal of the Kuku Agricultural Dairy Project – Sudan; the width of canal at the upper side from ridge to ridge is about 6m and the depth about 3m. Using this combination boom mechanism inside the canals under the different pressures and working speeds better spray results were achieved. The results obtained showed that the high average nozzle flow rates was 0.79l/min. at pressure rate of 3 bar and the speed was 7 km/hr ,and as the pressure rate was increased from3 bar to 4bar the flow rate increased from 0.79 to 1.35l/min at the same speed /(7 km/hr) by 71%. Also the results showed that the spraying rate increased from 55.9 to 61 .8 L/fed at pressure 3bar. Statistical analysis showed a significant effect on nozzle flow rate when using different speeds. As the pressure rate increased from 3 to 4 bars, this resulted in a significant effect on nozzle flow rate.

Keywords: Horizontal boom, Vertical boom, Spraying unit system and Support unit

Introduction

Due to the global demand for food items, the increased costs of mechanization on the farm and the current disposition of financial institutions towards agricultural credits, it became very critical for existing farmers, farm managers, and agricultural investors to make informed decisions based on figures, and to improve the management of mechanization operations (AbuSwar, 2005).

With policy and economical encouragement, the planting acreage of fodder and other crops which irrigated by surface irrigation increased year by year in Sudan.

Khartoum State the capital of Sudan is an important area for fodder production to satisfy the requirement of increasing animal numbers for meat and dairy products, the demand for which is continuously increasing due to normal population growth and mass immigration of rural communities to the capital towns and other settlements. In addition to this, a remarkable activity for cattle and sheep for export has resulted in increasing the area of fodder crops (Aidaroos, *etal*., 2017).

The standard of maintenance of irrigation and drainage is poor in many irrigation systems throughout the world Inferior management of those weeds growing in the channel, aquatic weeds leads to a number of economic, social and environmental problems, (Wang Bo, *et al*., 2011).

With the wide range of chemicals available it is most important that the appropriate herbicide be used for any particular weed.

Excessive vegetation can make inspections, regular maintenance, and emergency response measures more difficult. Overgrown vegetation can obscure canal embankment and prism slopes, making it difficult to perform visual inspections and detect issues such as seepage, boils, cracking, sinkholes, settlement, displacement, deflection, animal burrows, or other signs of problems. Early detection of developing issues is key to avoiding canal failures, (Aidaroos, *et al*., 2017).

The controls of Aquatic weeds that cause problems by blocking the flow of water in irrigation channels are an important and necessary process and that the process of cleaning and cleanliness of canal and irrigation water channels before each season is estimated at very large amounts affect the profitability of the crop and the purpose of agricultural investment. Weeds reduce delivery capacity, clog pumps and prevent us from providing an efficient service to the farmers and customers. The most effective way for us to deal with weeds growing in supply channels is to treat them with a Safe herbicide (Ministry of Animal Resources, 2007)

The mechanism of excavators used to eradicate weeds from within irrigation canals in most agricultural projects in Sudan are considered costly, the duration of the cleaning is quite large, not always available and at present, the activity of these machines has changed to other profitable activities like mining the gold in north and west of Sudan.

Currently, most of the machines that used in the spraying herbicides are designed to operate on flat surfaces and open fields (Fig. 1) and can be difficult to be used to spray pesticide solutions inside the irrigation canals. Therefore, the general objective of the present work is to modify and design a new type of sprayer boom mechanism for weeds control in irrigation and drainage canals. The new design used a combination of horizontal and vertical structure to meet all-directional spraying, especially to control weeds and eliminate insect and pests that hide in the reverse side of plant leaves efficiently. It is important to note that the new-designed boom mechanism is suspended from a tractor and the old sprayer boom, which has a special structure and can move easily inside the irrigation canal and with a row spacing of 500mm even if the irrigation canal depth is about 30 mm to 3000 mm.

Specific Objectives:-

- To measure the nozzle flow rate (L/min).
- To find the application rate (L/fed).
- To determine droplet size distribution.

Material and Methods

The overall Structural design and assembly

The new boom mechanism showed in Fig. 2 is connected to the old sprayer boom which mounted to the rear of the tractor. Mostly, sprayer boom is designed as trusses structure, which can be divided into several individual parts and folded up by a hydraulic cylinder. The spray nozzles are located with same spacing at the bottom of the boom, as showed in Fig.1.

Fig.1: Common sprayer boom

Key parts design

The new design (Fig. 2 a, b and c) consists of two main units: mainly, spraying unit and spray pipes support unit.

The spray unit consists of horizontal spray main pipe line fed from the sprayer tank through a pump, and the vertical lateral pipe line that connected to the main line where the sprayer nozzles are located on its bottom side. The lateral pipe line length can be changed as from 300 mm to 3000 mm to fit different depths of channels. These lateral pipe lengths are 300, 500. 700 and 1500mm, and can be connected together with special metal connecters according to the depth of channels (Fig. 3 a, b, c and b). The distances between lateral pipe lines and nozzles along the boom were set by equal distance of 500 mm as have been recommended in order to allow for overlapping rates of spray pattern.

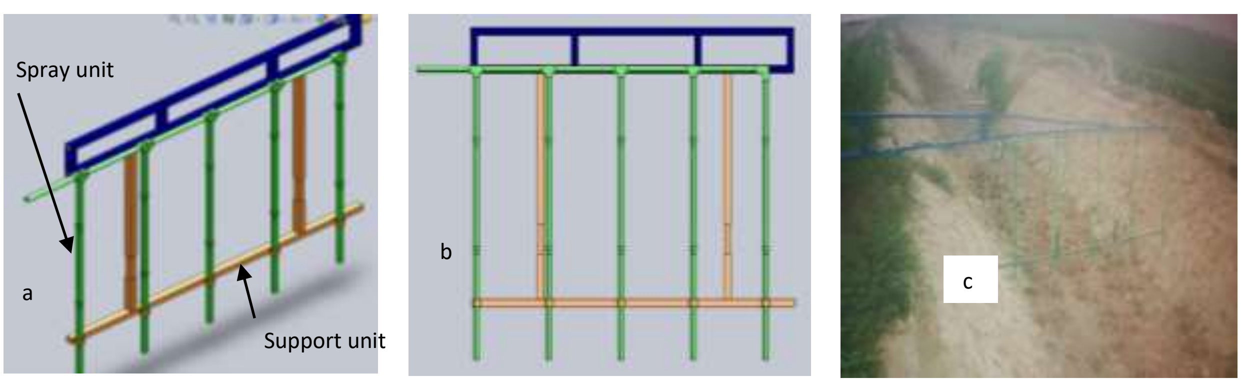


Fig. 2: Three-dimensional prototype presentation isometric (a) and elevation view (b) and photographic view of the new design inside the canal (c)

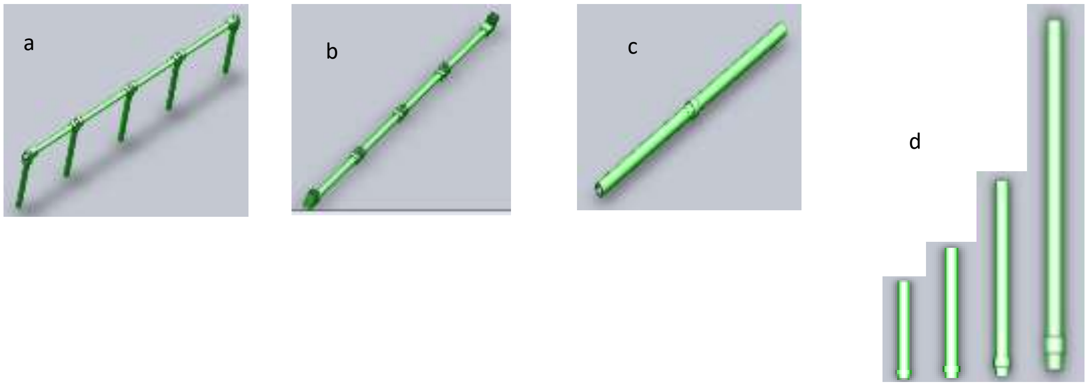


Fig. 3: Three-dimensional prototype presentation of (a) isometric of the spraying unit (b) horizontal spray main pipe line (c) special metal connecters and (d) The 300, 500. 700 and 1500mm lateral pipe line

The support unit is designed to support lateral spray pipes to limit their horizontal and vertical vibration movement to maintain the spray pattern overlap. The system consists of a vertical telescopic square metal pipe so that their heights can be changed from one to two meters. These vertical pipes are connected at the bottom part to the horizontal square metal pipe with a circular metal rings spaced 500 mm a part, to allow the lateral pipes to pass through in order to maintain vibration movement (Fig.4a, b, c and d).

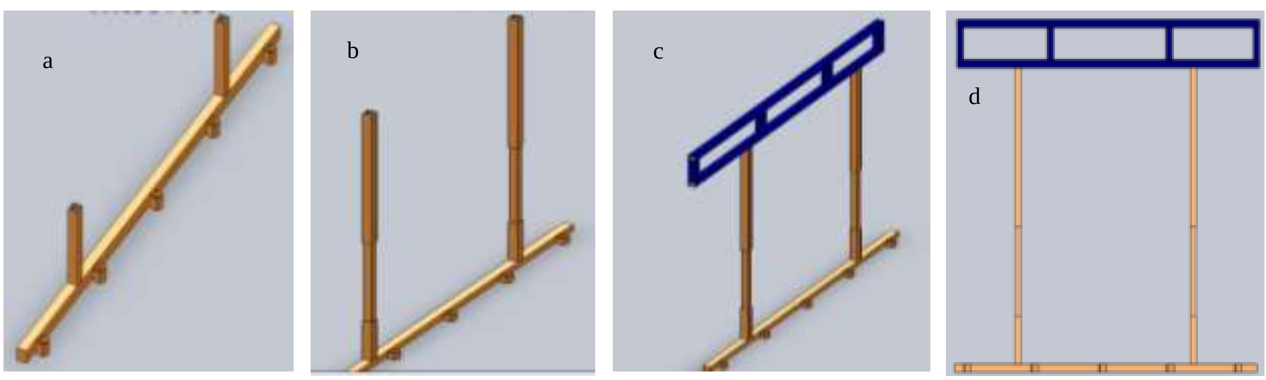


Fig. 4: Three-dimensional prototype presentation of a. the horizontal square metal pipe with a circular metal rings. B. a vertical telescopic square metal pipe c. isometric of the support unit d) elevation view of support

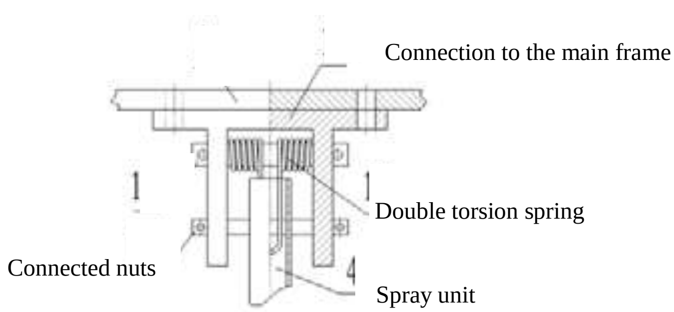
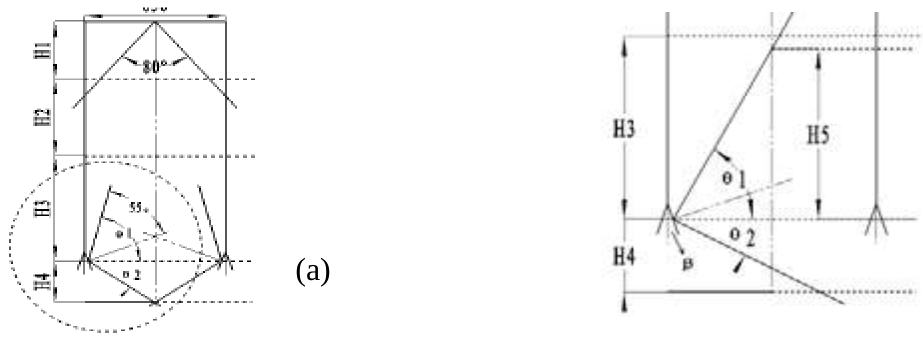


Fig.5 Semi sectional view of the flexible connection

Design for Flexible connection. a flexible connection was designed to connect the vertical boom to the sprayer main boom. A double torsion spring was installed in the connection. With this mechanism, the vertical boom would rotate around the boom axis while the drag force facing the machine inside the canals, avoiding boom broken off caused by undue resistance. The semi sectional view of the flexible connection was shown in Fig.5

Judgment basis and method for optimal parameters of structure; the new-designed boom mechanism aims to get better spray quality. Droplets distribution uniformity, drift and coverage ratio are main indices of appraising spray quality. For this combination boom mechanism, more consideration have been focused on the first and the last indices in the design process, which are mainly affected by the length of vertical boom and the angle of branch boom. Therefore, some researches as follows were done to determine the parameters mentioned above.



(a) (b)

Fig. 6 Sketch of parameters relationship

As showed in Fig.6 (a), the combination boom was designed as a gate-type boom. Each row in side canal received spray mostly from one top nozzle and a couple of branch nozzles. It is necessary to keep a certain distance between nozzle and the best spray target area, which is represented byH_0, and

$$H_0 = H_1 + H_2 \qquad (1)$$

in which, H_1 the distance between the top nozzle and the top of plant, value for 300mm in this design, H_2 the distance between the top of plant and the best spray target area. This deal was done to meet demand and avoid pesticide damage in the meantime. The length of the vertical boom was indicated by H_L, which is defined as,

$$H_L = H_1 + H_2 + H_3 \qquad (2)$$

Where:

H_3 is the flexible length, which was related to the upward spray scale of the branch nozzle. As a result, the spray scale of plant exposed in the vertical plane that executed by the combination of boom is given as,

$$H_T = H_2 + H_3 + H_4 \qquad (3)$$

Where:

H_TIs the spray scale of combination of boom in the vertical plane, H_4 the downward spray scale of the branch nozzle in the vertical plane; obviously, the downward spray scale was decided by the angle of the branch nozzle.

From the theory of spray distribution uniformity, it is known that nozzle installation height, nozzle angle and space are important factors. Among the three factors, space has already been decided as

500mm. Based on the principle that smaller angle nozzle is used for high density plants; standard flat spray nozzle 80°was chosen as the top nozzle that was installed at the bottom of the horizontal boom. Besides, flat nozzle 110° was selected to be installed on the branch boom to get a wider coverage in the vertical plane. As the first factor, nozzle installation height means the top nozzle fixed height in this mechanism. Theoretically, it is deemed to be the best condition that there is once overlap of neighboring spray placement, as showed in Fig. 7.

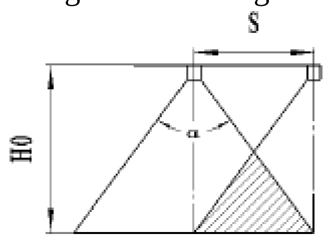


Fig. 7: Optimum neighboring nozzles placement

Experimental site, design and treatments applications:

The field experiment was carried out at the main irrigation canal of the Kuku Agricultural Dairy Project – Nile East Locality-Sudan; where the width of canal at the upper side from ridge to ridge is about 6m and the depth about 3m.

In this study, a factorial experiment was arranged in a split plot design with three replicates for each, the two forward speeds (5 and 7 km/hr) were assigned to the main plots while the two pressure rates (3 and 4 bar) were distributed to the sub-plot respectively, giving a total of 12 plots. The treatments were randomly distributed in the main plot and sub plot,

Measurement

The following performance parameters were determined to evaluate the new design:

Nozzle discharge test was done to evaluate the amount of liquid discharge from each nozzle and to check the variation between the discharge rates of each nozzle within 30 meter and discharge data was collected and time taken for each trial was recorded. The discharge from each nozzle was collected by tying a plastic bag on each nozzle. After each 30 m interval the sprayer was stopped, as the sprayer stops each liquid collected from the nozzle was measured using measuring cylinder. Coefficient of variation was used to analyze variation of discharge rate among the nozzles for each trial.

Droplet size diameter:

- The sensitive paper card was distributed randomly inside the dry irrigation canal mainly experimental area. The collection of the droplets size was measured under the microscope and the following formulas of Nasr (2008)was applied:

$$droplet\ surface\ mean = \sqrt{\frac{\sum N D^2}{\sum N}} \quad (4)$$

$$droplet\ volume\ mean = \sqrt[3]{\frac{\sum N D^2}{\sum N}} \quad (5)$$

Where: N= Number of droplets; D= droplet diameter in micron

Application rate: the application rate was measured for the two pressure rates at the two spraying speeds and it was calculated using the following formula (Nasr, 2008).

$$Application\ rate\ \left(\frac{L}{ha}\right) = \frac{sparayer\ discharge\ \left(\frac{L}{hr}\right) \times 10}{spraying\ width\ (m) \times spraying\ speed\ \left(\frac{km}{hr}\right)} \quad \ldots\ldots\ldots\ldots\ldots (6)$$

Results and discussion

A hydraulic sprayer boom was designed and by it full width (3m). It was equipped with give spray nozzles for spraying chemical materials to control weeds and grasses that grass inside irrigation canals and Abu 20 channels.

Field evaluation was done to test the boom performance using different forward speeds (5 and 7km/hr) at different operating pressures mainly 3 and 4 bar.

1. **Effect of different speeds and pressure rate on nozzle flow rate:**

   Table (1) shows the nozzle flow rate (Lit.//min.) at two different speeds (5 and 7 km/hr) using two operating pressures rates mainly 3 bar and 4 bar.

   The results obtained showed that the high average nozzle flow rates was 0.79l/min. at pressure rate of 3 bar and the speed was 7 km/hr> as the pressure rate was increased from3 bar to 4bartheflowrateincreasedfrom0.79to1.35l/min at the same speed / (7 km/hr) by 71%

   Statistical analysis given in Table (2) showed a significant effect on nozzle flow rate when using different speed. As the pressure rate increased from 3 to 4 bars this resulted in a significant effect on nozzle flow rate.

2. **Effect of different speeds and pressure rate on application rate:**

   Table (3) showed the spraying (application) rate (L./hr) and (L./ feddan) at different speeds and pressure rate. From the table it is clear that there is an increase in spraying rate from 55.9 to 61.8 L./feddan at the operating pressure rate of 3 bar, when speed was increased from 5 to 7 km/hr. on the other hand the spraying rate (L/fed.) decreased from 121.6 to 105.7 L/fed by 13% when using operating pressure of 4 bars at the second speed 77km/hr.

3. **Effect of different speeds and pressure rate on droplet size diameters:**

   Spray droplet size diameters were measured when using the second speed (7 km/hr) for the two different pressure rates (3 and 4 bars). Table (1) showed the values registered in micron at the two pressure rates. It was found that the spry droplet size diameter decreased at pressure rate 4 bar by 7.4%.

Table 1: Nozzle flow rate (Lit/min) at two different speeds using two operating pressures rates

	Sp 1 (5 km/hr)		Sp 2 (7 km/hr)	
Nozzle flow rate	Pressure 1 (3-bar)	Pressure 2 (4-bar)	Pressure 1 (3-bar)	Pressure 2 (4-bar)
1	0.48	1.15	0.72	1.22
2	0.41	0.48	0.62	1.18
3	0.86	1.82	1.34	2.1
4	0.46	1.22	0.74	1.33
5	0.36	0.86	0-53	0.96
Droplet size diameters	1070 micron	1005 micron	1080 micron	1000 micron

Table 2: Analysis of variance for nozzle discharge

Sources	DF	SS	MS	F	P
Speed	1	0.34585	0.34585	16.66	0.015
Pressure	1	1.67620	1.67620	52.81	0.000
Speed*pressure	1	0.25390	0.3174		

Table 3: application rate at two different speeds using two operating pressures rates

	Sp 1 (5 km/hr)		Sp 2 (7 km/hr)	
Application rate	Pressure 1 (3-bar)	Pressure 2 (4-bar)	Pressure 1 (3-bar)	Pressure 2 (4-bar)
Lit./hr	153	333	228	405
Lit./ fed.	55.9	121.6	61.8	105.7

Conclusions:

A hydraulic sprayer boom was designed and by it full width (3m). It was equipped with give spray nozzles for spraying chemical materials to control weeds and grasses that grass inside irrigation canals and Abu 20 channels.

Field evaluation was done to test the boom performance using different forward speeds (5 and 7km/hr) at different operating pressures mainly 3 and 4 bar.

Acknowledgments

The authors highly acknowledged the Deanship of scientific research, Sudan University of Science and Technology for financial support. The authors also express appreciation for Agricultural Engineering Staff members for their holistic support throughout the experimental work.

References:

AbuSwar, A.O. (2005). Forage crops Production in Sudan, 1st edition. Khartoum Press house. Sudan. pp: 34 and 104.

Aidaroos, S.A. ,ELmahdi, E.A. and Dagash Y.I. (2017). Effects of Irrigation Intervals and Sowing Methods on Fresh and Dry Matter Yield of Two Fodder Sorghum Cultivars. SUST Journal of Agricultural and Veterinary Sciences (SJAVS) Vol. 18 No.(2). Pp 16-22.

Nasr, Jamal eldeen M. (2008) Agricultural machinery. College of Agriculture – Cairo University.

Ministry of Animal Resources (2007). Sudan, Annual Report.

Wang Bo, Dong-xing Zhang and Wei Lan. (2011). A new boom mechanism design for corn sprayer. International Conference on Mechanical Engineering and Technology ICMET 2011 November 24-25, 2011, London, UK.

تصميم وتقييم آلية جديدة لحامل بشابير لالة رش هيدروليكية لمكافحة الحشائش في قنوات الري

عبدالله نورالدين عثمان خيري، ميسرة أحمد محمد

قسم الهندسة الزراعية، كلية الدراسات الزراعية، جامعة السودان للعلوم والتكنولوجيا

المستخلص:

يعتبر مستوى صيانة قنوات الري والصرف ضعيفًا في أغلب أنظمة الري في جميع أنحاء العالم. يؤدي وجود الأعشاب المائية إلى عدد من المشاكل الاقتصادية والاجتماعية والبيئية. مع توافر مجموعة كبيرة من المواد الكيميائية الآمنة، فإنه من المهم للغاية استخدام مبيدات الحشائش المناسبة لأغراض مكافحتها كيميائيا؛ حاليًا، معظم الآلات المستخدمة لعملية الرش تستخدم لرش الأسطح المستوية والحقول المفتوحة ولا يمكن استخدامها لرش محاليل المبيدات داخل قنوات الري. لذلك، هدفت هذه الدراسة العمل إلى تصميم وتصنيع آلية جديدة لحامل البشابير الهيدروليكي لمكافحة الحشائش داخل قنوات الري يتضمن التصميم الجديد علي حاملا أفقيًا ورأسيًا ، وآلية اتصال مرنًة، وذراعًا فرعيا ، وذراع إسناد. بالجمع بين النظريات وطرق انتظامية توزيع الرش والتغطية الفعالة لقطرات الرش ، تم تحديد مقياس الرش للحامل الرأسي لخط الأنابيب بما يساوي 3000 مم.تم إجراء عملية التقييم للتصميم الجديد من خلال إجراء تجربة حقلية في قناة الري الرئيسية لمشروع ألبان كوكو الزراعي بالسودان ؛ يبلغ عرض القناة حوالي 6 أمتار وبعمق حوالي 3 أمتار. تم تحقيق نتائج رش أفضل وذلك عندنا استخدامنا لآلية حامل البشابير والعمل بها داخل القنوات تحت ضغوط وسرعات عمل مختلفة.أظهرت النتائج أن أقصي متوسط معدل رش للبشابير هو 0.79 لتر / دقيقة عند ضغط 3 بار وسرعة أمامية 7 كم / ساعة ، بزيادة معدل الضغط من 3 بار إلى 4 بار ادي الي زيادة معدل الرش من 0.79 إلى 1.35 لتر / دقيقة عند السرعة / (7 كم / ساعة) بمقدار زيادة 71%، كذلك أشارت النتائج حدوث زيادة في معدل الرش من 55.9 إلى 61.8 لتر / فدان عند ضغط 3 بار. أظهر التحليل الإحصائي تأثيراً معنوياً على معدل رش البشابير عند استخدام السرعات المختلفة. مع زيادة معدل الضغط من 3 إلى 4 بار ، نتج عن ذلك تأثير كبير على معدل الرش.