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A Metering Nano Fertilizer Incorporated with Potato Planter

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ABSTRACT

A potato belt bed planter was modified by adding a precision mechanical device for nano fertilizers. It was consisted of a steel land wheel transmitted the motion to a metering unit via a transmission system designed to operate without effect on its performance. The planter was tested at five metering gate width of 5,10,15,20, and 25 mm, five metering rotary distributer reduction ratio at four planting forward speeds 0.97, 1.11, 1.25 and 1.39m/s. The results indicated that the required application rate (0.028 Mg/feddan) was achieved at reduction ratio between the land wheel and fertilizer rotary distributer (1:1.56), it was 0.0299,0.0297,0.0288, and 0.0291 Mg/feddan at forward speeds 0.97,1.11,1.25, and 1.39 m/s respectively. The field capacity before and after the modification was 1.5, 1.67, 1.82, and 2.01 feddan/h at forward speeds 0.97, 1.11, 1.25, 1.39 m/s respectively. The specific energy was 7.20, 8.29, 7.15, and 7.30 kW.h /feddan at forward speeds 0.97, 1.11, 1.25, 1.39 m/s respectively. The planter total operating costs without modification was 568.5 EGP/h and 605.5 EGP/h with modification. The cost of planting one feddan without modification was 312.3 EGP and 332. 7 EGP with modification. The planter indicated (NPV) of 41666.4EGP at 14 % interest rate. Also, the planter (PBP) was 3.1 year. The potato average yield in the experimental area with Spunta variety was 15.1 Mg/feddan with common fertilization and 16.2 Mg/feddan with nano fertilization. This means the modification success to add the required amount of fertilizer and added 2199.6 EGP to each feddan profit.

Keywords: Nano fertilizer, Fertilizer metering system, Micro granules

INTRODUCTION

Recently, there is additional consideration for using advantages of nanotechnology treatment in agricultural sector by providing diverse nanomaterials. Nano fertilizers have many returns i.e. increasing crop yield, slow distributing, decreased environmental contamination, develop soil fertility, and make a feasible environment for microorganisms. It is very essential to optimize the utilize of chemical fertilization for crop nutrient necessities to minimize the threat of environmental pollution by trying other methods of fertilization using new technologies for example nano technology (Manjunatha *et al.,* 2016). Also, he added that Nano fertilizers could improve interaction and efficient uptake of nutrients for crop fertilization. The word nano material is commonly used for materials with a size ranging between 1 and 100 nm with rare physicochemical properties, i.e. excessive surface area, high reactivity, tunable pore size and particle morphology, which rise from their small size, shape, surface area, conductivity (Rai and Ingle, 2012).

Plant cell walls have aperture diameters ranging from 5 to 20 nanometer (Fleischer *et al.,* 1999). Nano scale fertilizers could maybe lead to more effective transfer of nutrients as their small size may allow them access to a diversity of plant surfaces and transport channels (Liu *et al.,* 2009). May and Kocabiyik (2019) mentioned that most wanted fertilizer quantity per unit area is one of the majority important criteria in formative the fertilizer metering performance of applicators for plant making. Development of various purpose methods and metering systems with different advantages has been enduring for years to apply the desired fertilizer amount at high truth.

The agglomeration of fertilizer is one of the criteria for measuring the quality of fertilizer appearance. Avoiding agglomeration is an essential link in fertilizer production (Ahmad *et al.*, 2017; Tyc *et al.*, 2019; Zafar *et al.*, 2017). Jakiene *et al.*, (2015) reported that bio-organic nano fertilizer at single 1 liter per hectare amount in sugar beet plants added root biomass by 42.6%, net photosynthetic productivity by 15.8%, root yield by 12.6%, sucrose content by 1.03 % and yield of white sugar by 19.2% in difference with the untreated beets. Liu and Lal (2015) reported that the application of nano particles to sugar beet plants can be valuable for growth and development due to its facility for greater absorbance and high reactivity.

Klenin, et al., (1985) indicated that the variation in size of element fertilizers, hygroscopicity, dispersibility, density, movement to distribute and cake and other properties affecting the functioning of machines fabricated. They added that the mineral size has an important influence on machine working, as granule size rises above 5mm; they turn into increasingly weaker principal to poor scattering. Hygroscopicity of fertilizers, in most situations, reveals their properties, which directly effect of the machines qualitative guides operation. Dispersibility of fertilizers is controlled by their moisture content, which depends on their hygroscopicity. Scattering of fertilizer granules is explained as their ability to form an arc over orifices. Song et al., (2016) establish that if the fertilizer particles of the

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equivalent volume are high in roundness and the specific surface area of the particles is minor, the particles contact through the summit with large porosity, which is hard to bridge and agglomerate. Otherwise, if the fertilizer particles have a little roundness, and the specific surface area of the particles is huge, then the particles contact through the surface with little porosity, and it is easy to bridge and agglomerate. The fertilizer sphericity can be used to distinguish the roundness of the fertilizer. Therefore, in real work, the appearance of a fertilizer can be assessed by fertilizer sphericity (Pei *et al.,* 2015). The sphericity size technology can generally be separated into two types: contact measurement and non-contact measurement (Michihata *et al.,* 2014).

The contact measurement method is the main way to measure the sphere at present. The radial method for measuring the rotating specimen the threedimensional sphericity worth through a series of twodimensional circularity principles obtained by the roundness measurement system and statistical procedures (Kanada, 1997). Huang *et al.,* (2016) proposed a meridian measurement way, using a roundness meter to gain a series of circular roundness faults on the measured spherical surface to calculate its sphericity. Kung *et al.,* (2007) proposed an ultra-precision micro-CMM system that uses a little measuring force three dimensional trigger probe to reach high-precision measurement of microspheres. The non-contact measurement method is flexible and rapid processing and has a good image reproduction and an effective anti-interference capacity in the field. Bartl *et al.,* (2010) uses a two-way measurement method to get the reconstruction of the absolute sphere size, via the self-developed spherical Fizeau interferometer shared with splicing technology. Studies on the structural properties, location, flute type and size associated with the fertilizer roll have been accepted out throughout the development time of fertilizer units mount planter (Gurjar *et al.,* 2017). These units are operated by method of the transmission of motion from the planter wheel via mechanical transmission components such as chain-sprocket, gear groups and shafts. Fertilizer submission rate is tried to be corrected by changing the speed of the fertilizer roll or the energetic flute length, however there are lots boundaries even though they are generally expected to have sufficient operation. Undesired instances for example skidding due to the pressure on the machine wheel fall in the chain-gear systems and shakings may occur through the transmission of the mechanical transfer from the wheels to the fertilizer unit at high speeds.

Studies have been carried out on different hydraulic, pneumatic and electronic controlled adjustment systems for a more perceptive fertilizer application rate adjustment with respect to the fertilizer applicators and new studies are yet ongoing. Level adjusters were developed to raise the effectiveness of fertilizer units. DC motor-linear action (Tola *et al.,* 2008), pneumatic (Talha *et al.,* 2011), hydraulic motor (Koundal *et al.,* 2012), DC motor-linear action (Chandel *et al.,* 2016; Tewari, 2015), linear actuator (Van *et al.,* 2018), hydraulic motor and proportional flood control electro-valve (Reyes *et al.,* 2015) and double-acting pneumatic cylinder (Alameen *et al.,* 2019) can be set as examples. The general point of these level adjusters is the changing of the operating area of the fluted roller with the developed system except a mechanic fertilizer roll rotation movement at constant transmission ratio. Forouzanmehr and Loghavi (2012) carried out a study on step motor fertilizer application rate adjuster that switch the speed of the fertilizer roll toorganize overcome the aforementioned issues related to the mechanical drive and transmission systems.

Micro-granular starter fertilizers are preferred in recent years asanalternative of classical granular fertilizers due to their return such as the ability to be applied on the seed bed, lack of pyhthotoxic effect, low dose purpose, fast and strong root development and support of plants with better physical structures by impacting on vegetative development (Anonymous, 2019; Crista *et al.,* 2014; Ding *et al.,* 2018). Micro-granular fertilizers are directly applied in small quantities to the seed area or between the rows (Jankowski *et al.,* 2018; Wei *et al.,* 2015). The relatively steady nutrition element contents rise at the root region due to this care method. The nutrition elements support root growth and increase the nutrition consumption of plants from Fertilizer metering structures used for standard element fertilizers (Ø: 2–5 mm) cannot be used for micro-granular fertilizers since they vary from element fertilizers with a standard granular composition (application rate: 10–50 kg/da). The micro-granular fertilizers are applied at minor application rates such as 2–4 kg/da conditional on the product and they have a particle diameter (D) varying between 0.3 and 1.5 mm. It is detected that some companies in the world have rare model planters with micro-granular fertilizer part.

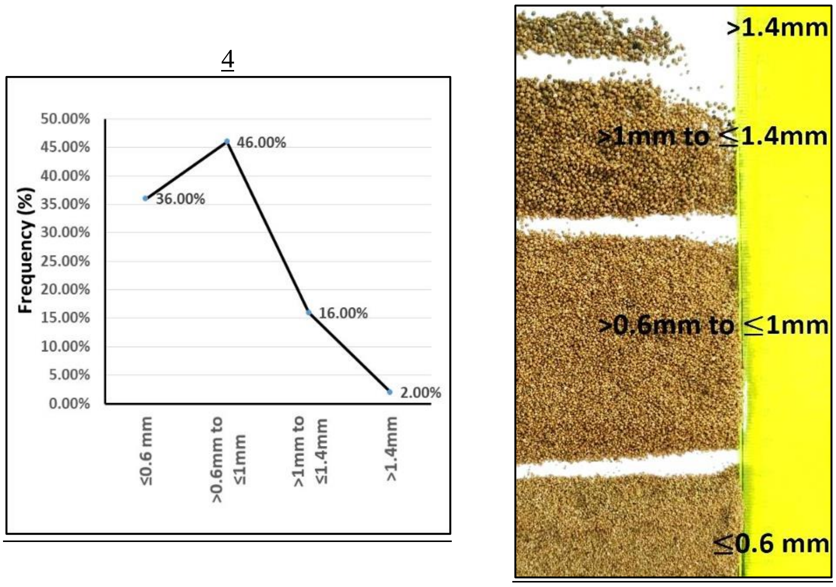
The targeted belt bed planter equipped with electronic system for dosing the micro granules, could not achieve the small required application rates for nano fertilizer. The objective of this research is developing a metering unit for nano fertilizer fitted on a high-speed potato bed belt planter. The metering unit is distinguished of simplicity, maintainability, and repairability. The system could achieve the small required amounts of fertilizers that not occurred with other systems.

MATERIALS AND METHODS

Some physical properties of Nano fertilizer

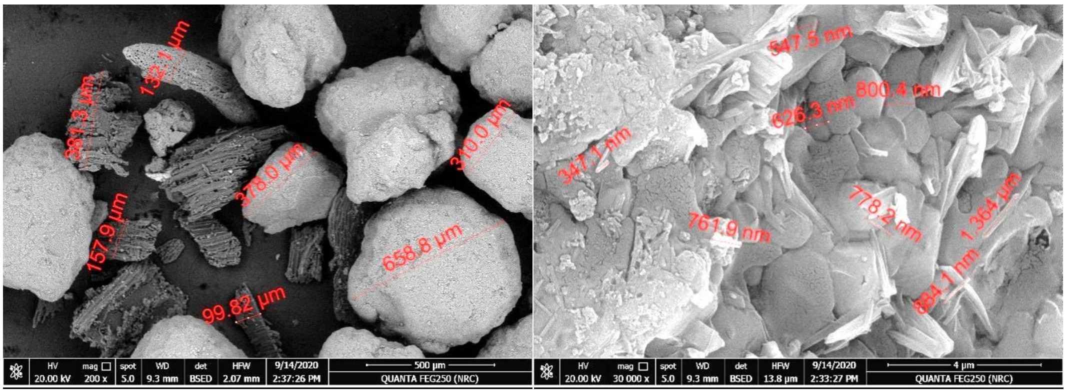
The nano fertilizer included (Nitrogen 11% + Phosphorus 50% + Chelatez Zinc 0.4 % and other contents) was used during experiments. The fertilizer bulk density was 0. 95 g.cm^{-3}, the repose angle was 25º, the friction angle with polyethylene was 20º.The diameters of the fertilizer granules were graded using vibrated sieves. The results indicated that the maximum value of the nano fertilizer diameter was 46% in category from (> 0.6 mm to ≤ 1 mm). Meanwhile, the minimum value was 2% in the category of (>1.4 mm).Fig. (1-A) shows a categorized frequency percentage of the nano fertilizer granules. Also,Fig. (1-B) shows an image nano fertilizer granules.

Also, an electronic microscope was used to measure the maximum particle size. The measurements find it was 0.6588 mm. Fig. (2-A) shows an image of the maximum particle size under the electronic microscope Quanta model of FEG250. Meanwhile, Fig.(2-B) shows an image of the nano partials in the granules.



(A). Categorized frequency percentage of the nano fertilizer granules diameter **(B). An image of nano fertilizer granules diameter**

Fig. 1. Categorized frequency percentage and an image of the nano fertilizer granules



(A). An image of the maximum granules size under the electronic microscope (Scale 1: 200) **(B). An image of the nano partials in the granules (Scale 1:30000)**

Fig. 2. Granuals and Partials under electronic microscope

The Nano fertilizer metering system

The nano fertilizer metering system was manufactured in a local workshop. The parts were designed and machined by a laser beam CNC machine. The modification was made to fit on one of the most common high-speed planters used to plant potato tubers in large areas in Egypt. A two rows belt bed planter, Structural made, model PM2, and Netherlands origin. The planter was used in the experiments in Nobaria, El-Behera governorate. Some numbers of this planter are equipped with a micro granules metering system controlled by the electronic circuit built in the planter control box. The electronic unit failed to work with nano fertilizer according to its physical specifications. the minimum adjustment gave 20 grams.m-1. The potato planter was equipped with a hydraulic tipping tuber hopper with a capacity of 2.5 m3. The planter trailed with an agricultural tractor equipped with narrow tires to pass through 1800 mm potato raised beds. On the other hand, the planter equipped with sterilization unit spraying the chemicals on the planting unit to prevent tuber diseasesthattransferred from land to another.

The idea of the modification was manufacturing a land wheel walking in the bottom of the right planted row and transfer the motion to a metering unit located in an upper place of the planter. The upper location was selected carefully to avoid the tipping of the tuber hopper. Thetelescopic transmission arm was articulated on a swinging point and designed to move up and down according to the land level.The fertilizer was moved from the metering unit via two plastic hoses to drop between inside the planting wings ,and mix with the tubers then covered with the soil by two covering discs.

The Nano fertilizer metering system was consisted of the following:

Main chassis

The main chassis was conformed of two vertical telescopic holders fitted on the main frame of the planter. Each telescopic holder was made of two squares hallow steel beams with dimensions of 80×80×3mm and 60 ×80×3mm. The required height was determined according to the position of the nano fertilizer tank. Two bolts and nut used to lock the telescopic chassis.

The transmission system

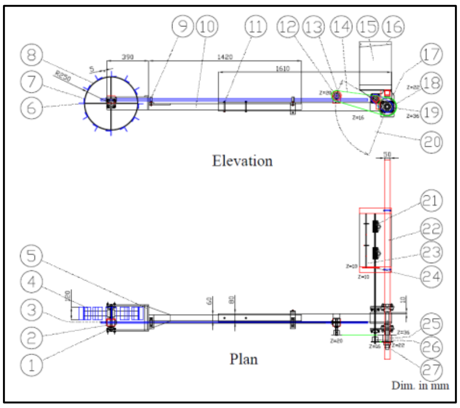
Metering land wheel

A steel wheel with radius of 250 mm was fitted on the telescopic arm by a steel wheel holder. The wheel was equipped with 12 grousers to increase the traction of the wheel. A steel skimmer was fitted on the wheel holder to clean the grousers from the soil. The wheel hexagonal shaft was rotated on two flanged bearing housing fitted on the wheel holder by bolts and locked nuts. The hexagonal wheel shaft was lathed to fit the inner diameter of the bearing.A rear hole in the wheel holder was made to ease the disassembling the wheel. A steel cable was fitted to the telescopic arm and attached to the planter opener chaises to rise during turning and move on the roads. Fig. (3). shows an image of the metering wheel. Also, Fig. (4). shows the schematic diagram of metering wheel.

Fig. 3. Metering land wheel

Telescopic transmission arm

The telescopic transmission arm was consisted of two steel square hallow beams with dimensions of 80×80×3mm and 60 ×80×3mm.Two bolts and nut used to lock the telescopic when its traction t5o the soil and set freely ona steel pillow.The job of the telescopic was holding the parts transmit the motion to the metering unit.The components of the telescopic arm are including in that Fig. (4).



(1) Bearing housing ;(2) Lowergear box;(3) Hexagonal transmission shaft ;(4) Grouser;(5) Soil skimmer ;(6) Steel land wheel ;(7) Grouser steel angle ;(8) Land wheel support ;(9) Hexagonal support bearing ;(10) Telescopic arm ;(11) Telescopic arm lock ;(12) Upper gear box;(13) Main idler Z 20;(14) Chain;(15) Nano fertilizer tank ;(16) Tank cover; (17) Bearing;(18) counter idler Z 22 ;(19) Main sprocket Z 36 ;(20) Telescopic arm articulation limits ;(21) Rotary distributor cylinder ;(22) Fertilizer tank fitting frame ;(23): Agitator;(24) Agitator sprocket Z 10 ;(25) Counter shaft;(26) Rotary distributer sprocket Z16 ;(27) Lock nut.

Fig. 4. A schematic diagram of the components of nano fertilizer metering unit

Transmission train

The metering wheel was moved between the potato raised bed in the front of the planter rear wheel.The motion was transmitted from the metering wheel to a small lower gearbox with reduction ratio of (2:1) then transmitted the motion to the upper gearbox with ratio of (1:2) via a hexagonal steel shift. The second gearbox transmitted the motion perpendicularly to a sprocket with 20teeth (Z 20) that transmitted the motion to an idler with 36 teeth (Z36) via a chain. A counter shaft was designed to be the center of the motion to prevent the chain to drop from the idler Z20 and free the swing articulation movement of the telescopic arm. the counter shaft was made of a cylinder lathed to fit two ball bearings outer diameter fitted inside the counter shaft and locked with inner ring pins. The bearings inner diameter was rotated on a 30 mm shaft.idlers with 36 teeth (Z36) and the Idler (Z 22) were welded on the outer diameter of the counter shaft.The idler Z 22 transmitted the motion to the Z16 sprocket that fitted with the square shaft of fertilizer unit. The final reduction ratio was 1:0.76.Fig.(5) shows the transmission components during manufacturing.

Fig. 5. Transmission components during manufacturing

Metering units

Nano fertilizer tank

A polyethylene tank with dimensions of 500 mm length of, 300 mm width , and 450 mm depth was fitted on a horizontal chassis made of a square hallow steel 50 ×50 mm with thickness of 5mm.The tank was equipped with an pins agitator to prevent any fertilizer conglomerate and takes its motion via idler and sprocket Z10.

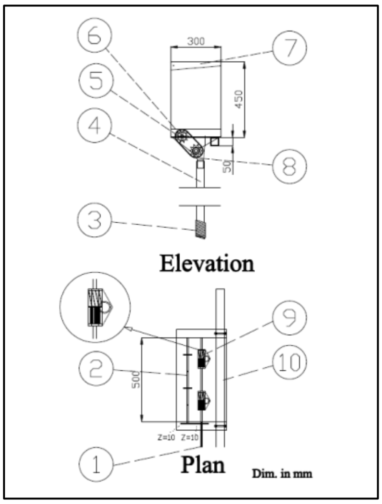
Metering units

Two metering units were fitted underneath the fertilizer tank. Each metering unit was consisted of a rotary distributor cylinder made from silicon and adjustable feeding gate. A collection cone was collected the dosed fertilizer then drop into a flexible shielded hose.

Nano fertilizer delivery tube

Two flexible shielded plastic hoses were fitted to the metering units to transfer the fertilizer to the planting area. A steel spring was fitted on the end of the hose to prevent fertilizer clogging due to the spraying antifungal in the planting unit. Fig. (6) shows an image the rotary distributor cylinder. Also, Fig.(7) shows the components of the metering units.

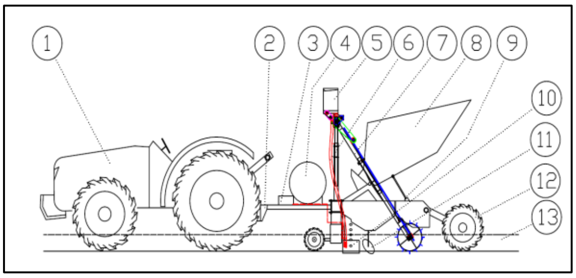
Fig. 6. An image of the rotary distributor cylinder



(1) Metering unit input shaft;(2) Agitator ;(3) Steel spring ;(4) Delivery tube;(5) Chain ; (6) Sprocket ;(7) Tank cover;(8) Idler;(9) Rotary distributer (10) Horizontal chassis.

Fig. 7. Components of the Nano fertilizer metering unit

Fig. (8) shows a out view of attaching metering unit that trailed by agricultral tractor equipped with narrow tires. The tubers dropped in planting area in the same time the metering wheel transmitt the mostion to the Nano fertilzer metering unit. The dose dropped into planting area and scattered with the tubers behind the planting opener via delivery tubes. A spraying unit stralized the openers .Two concaved discs cover the tubers and also stralized to prevent tuber diseases contamination. At the end of each row ,the driver begin to raise the planting unit from soil to make a turn. the planting unit connected to the nano fertilizer telescopic arm by a steel cable will surly raise it while machine turning. Also, Fig. (9) shows the assembling the metering unit on the potato planter.



(1)Narrow tires tractor ;(2)Hitch point ;(3)Spraying pump ;(4)Liqued stralization chemical tank ;(5)Nano fertilizer tank ;(6);Main Chsises ;(7)Telescopic arm;(8)Tubers tank;(9);Tipping tuber tank hydrulic cylinder;(10)planting opener;(11)Planted tubers covering discs;(12) Planter rear wheel;(13) potato rows.

Fig. 8. Sctehmatic diagram for attaching the metering unit with tractor

Fig. 9. Assembling the nano fertilizer metering unit on the potato planter

The potato planter

A two rows Structural belt bed high speed planter, model PM2, made in Netherlands was used in the experiments, the row distance was adjusted on 900mm.

Tractor:

A Kubota tractor M9000, 90 hp, water cooled, 4 cylinders, equipped with Narrow tires was used in the experiments.

Measuring instruments

-Weighing balance was used to measure the mass of collected fertilizers (accuracy of 1.01 g). Also, cotton textile bags were used to collect the dropped fertilizer from delivery tubes.

-Stopwatch to record the time consumed during calculation the forward speed during experiments.

-A canvas measuring tape of 30 m long, convoluted, was used during the experiments.

-The consumed fuel was measured by using a fuel consumption apparatus. It was calculated by filling the tractor fuel tank completely then, refilling the tank after making required treatment by measured flask, record the consumed time, then calculate the fuel consumption (*l*/h) at examined speeds loaded with the machine and unloaded.

-Electric oven was used to determine fertilizer moisture content at 75 $^{\circ}$C for 20 hours.

Testing procedure

The procedure for testing the fertilizer metering system was taken according to (Smith *et al*., 1994). The machine was operated over a level area for the distance required at the recommended speed of the planter and with the hopper half full. The planting cultures were removed.Fertilizer was collected in bags tied over each spout. At the nominal speed used for the application rate tests and with the average feed rate setting, test runs made over a distance of 5 m and its multiply then the average for 5 m taken. Each treatment was experimented 5 times and the average of read was taken. Each read was taken from average five-meter length. The fertilizer was collected from cloth bags and weighted. The agronomists advise to add the nano fertilizer with the tubers during planting, in this case lateral distribution of fertilizer is not required.

Test factors

The following treatments were studied to evaluate parameters affecting on the performance of metering unit:

- Metering gate width: Five widths of the dosing gate with width of (5, 10, 15, 20, and 25 mm).
- Metering rotary distributer reduction ratio: Five reduction ratio of rotary distributer as shown in Table (1).
- Four of average planting forward speeds: (0.97, 1.11, 1.25 and 1.39 m/s). Each forward speed was adjusted by selected tractor transmission gears and fuel hand lever.

Table 1. Changing the speed of the rotary distributer

Reduction ratio	Lower gearbox reduction ratio	Upper gearbox reduction ratio	Main idler	Main sprocket	counter idler	Rotary distributer sprocket	Final reduction ratio
R1	(2:1)	(1:2)	Z 20	Z 36	Z 22	Z 10	1:1.22
R2	(2:1)	(1:2)	Z 20	Z 36	Z 22	Z 12	1:0.76
R3	(2:1)	(1:2)	Z 20	Z 36	Z 22	Z 22	1:0.56
R4	(2:1)	(1:2)	Z 20	Z 36	Z 22	Z 28	1:0.44
R5	(2:1)	(1:2)	Z 20	Z 36	Z 22	Z 34	1:0.36

Measurements and calculations

- Application rate

Application rates in kg/feddan will be calculated from rates measured over 0.02381 feddan=100 m2 according to (Smith et al., 1994). The distance for each test run is calculated as follows:

$$\textbf{Length of test run in meters} = \frac{100}{Notmal\ width\ of\ the\ machine\ in\ meters} \quad \textbf{(1)}$$

- Land wheel skid (%): The distance that the machine moves forward for a given number of revolutions of the drive wheel will increase when the wheels skid. The machine will be slowly towed or pushed forward out of work and the distance travelled for five-wheel revolutions recorded (B). During field work, the distance for 5 wheel revolutions will again be measured (A). The percentage wheel slip is calculated as follows:

$$\textbf{Wheel skid (\%)} = \frac{A-B}{B} \times 100$$

- Field capacity (feddan/h).
- Determination of fuel consumption

Fuel consumption: The rate of fuel consumption as quantity per time unit with load and without load, as shown in the following formula (Suliman et al., 1993)

$$FC = \frac{f}{t} \times 3.6 \ldots\ldots\ldots\ldots\ldots\ldots \textbf{(2)}$$

where;

FC = Fuel consumption, l/h; f = volume of fuel consumption, $cm^3$and ,t = time, s.

The power and specific energy: The following formula was used to estimate power consumption. Hunt, (1983):

$$P = \frac{FC \times p_f \times LCV \times 427 \times \eta_{th} \times \eta_{mec}}{3600 \times 75 \times 1.36} \ldots\ldots\ldots (3)$$

where;

P= power (kW)
FC= Fuel consumption, *l*/h;
p_f =Density of fuel, kg / *l* = 0.85 (for diesel fuel),
LCV=Calorific value of fuel (10000 kcal / kg),
427= Thermo-mechanical equivalent, J / kcal,
η_{th}= Thermal efficiency of engine (≈ 35% for diesel engines)
η_{mec}= Mechanical efficiency of engine (≈ 80%).

The specific energy was calculated by using the following equation:

$$\textbf{\textit{Specific energy (kW.h /feddan)}} = \frac{Power\ requirment\ (kW)}{Effective\ feild\ capacity\ (\frac{Feddan}{h})} \ldots \textbf{(4)}$$

(5) Modification cost analysis:

The cost analysis was calculated according to Oida, (1997). It performed in two steps. The first step is to calculate the cost of the materials and manufacturingof the modification. The second step is to calculate the planter operating cost with the modification.

These costs include depreciation (D), annual capital interest taxes (I), housing and insurance (THI), repair and maintenance(R), and labor cost (L).

$$T_c = \frac{\{[(D)+(I)+(THI)]+[(R)+(L)]\}}{n_a} \ldots\ldots\ldots\ldots\ldots \textbf{(5)}$$

where;

Tc= Total cost, LE/h;
$n_a = \pi$= Annual working hours = 500 h/year (two seasons)

$$Tc = \frac{\left\{\left[\left(\frac{Pc-Sv}{Y}\right)+\left(\frac{(Pc+Sv)}{2}\times\frac{i}{100}\right)+(0.02\ Pc)\right]+\left[\left(\frac{Pc\times R_c}{Y}\right)+(N_l\times L_c\times n_a)+Fo\right]\right\}}{n_a} \ldots \textbf{(6)}$$

where;

Pc= Potato planter price include the modification, EGP;
Sv = Salvage value=5% from the potato planter price EGP;
i= Interest rate =14%;
Rc= Coefficient of repair and maintenance = 100%;
Y= Machine age = 5 years;
$N_l = \pi r^2$= No. of workers = one tractor driver;
L_c=Labor cost = 200 EGP/day, day (7 hours), EGP/h;
n_a=π= Annual working hours = 500 h/year;
Fo=Fuel and oil cost, EGP/h.

RESULTS AND DISCUSSION

The experiments were carried out in a reclaimed pivot irrigated area in Nobaria, Behera governorate. The planter was used with nano fertilizer with moisture content of 0.24 %. The tank was filled to the half level. The tuber tank was filled with Sponta variety potato tubers. Also, the planting parts sterilization tank was filled with anti-Fungus solution. The planter was moved between raised beds 180 cm. the land wheel was move between the raised beds in the front of planter wheel.The experiments were made to find the effect of metering gate width, rotary distributer speed, and planting forward speeds on fertilizer application rate. Each treatment was experimented 5 times and the average of read was taken. Each read was taken from average five-meter length. The fertilizer was collected from cloth bags and weighted.

Effect of metering gate width at different planting forward speeds on fertilizer application rate

The experiments were carried out in potato fields. The spacing between rows was 90 cm. five gate widths of (5, 10, 15, 20, and 25 mm) were used at four forward speeds of (0.97, 1.11, 1.25 and 1.39 m/s) to determine the optimum gate width that achieve the required application rate. Each treatment was experimented at 3 times and the average of reads was taken. The transmission reduction ratio was R3 (1:1.56). Each read was taken from average of five-meter length. The fertilizer was collected from cloth bags and weighted. The required performance rate was 6 g / $\overline{\boldsymbol{m}}$ equaled 0.028 Mg/ feddan. Fig. (10) shows the effect of metering gate width at different planting forward speeds on fertilizer application rate.From Fig. (10), it realized that the maximum performance rate was 0.05505 Mg/feddan at forward speed 0.97 m/s under dosing gate width of 25mm. Mean while the minimum performance rate was 0.0105 Mg/feddan at forward speed 1.39 m/s and dosing gate width of 5mm. At the gate width of 5 mm and by increasing the forward speed from (0.97 to 1.11, 1.25, 1.39 m/s) the application rates were decreased by1.07, 2.41, 6.42% respectively, where the wheel skid percentage were (0.64, 1.29, 1.55, and 2.61% at the tested speeds (0.97, 1.11, 1.25, and 1.39 m/s) respectively. The results take the same trends at gate width of 10,15,20, and 25 mm.

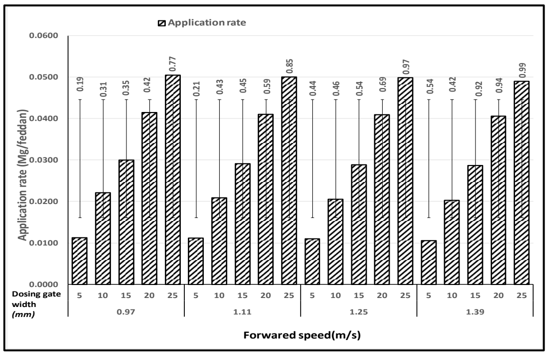


Fig. 10. Effect of metering gate width at different planting forward speeds on fertilizer application rate

The application rate is extremely effect by the slip ratio at the forward speed. On the other hand, the experiments were made on the machine in standing position by rotating the land wheel five times. The application rate was 0.0119, 0.0235, 0.0318, 00441, and 0.0530 Mg/feddan at gate width of 5,10,15,20, and 25 mm respectively. The results indicated that the optimum gate width is 15 mm that achieve application rate of 0.0300, 0.0290, 0.0288, and 0.0287 Mg/feddan at speeds of 0.97, 1.11, 1.25, 1.39 m/s respectively. The results were near to the required application rate (0.0280 Mg/feddan).

Effect of rotary distributer reduction ratio to the land wheel at different planting forward speeds on fertilizer application rate

Five transmission reduction ratios of the rotary distributer (R1, R2, R3, R4, and R5) were tested at four forward speeds of (0.97, 1.11, 1.25 and 1.39 m/s) to determine the optimum transmission reduction ratio that achieve the required application rate at the optimum gate width of (15 mm). Each treatment was experimented 5 times and the average of read was taken. Each read was taken from average five-meter length. The fertilizer was collected from cloth bags and weighted.

Fig. (11) shows the effect of rotary distributer speed comes from the reduction ratio between the land wheel at different planting forward speeds on fertilizer application rate. From Fig. (11), it is found that the maximum performance rate was 0.0640 Mg/feddan at forward speed 0.97 m/s reduction ratio R1, Meanwhile, the minimum performance rate was 0.0089 Mg/feddan at forward speed 1.39 m/s and reduction ratio R5.

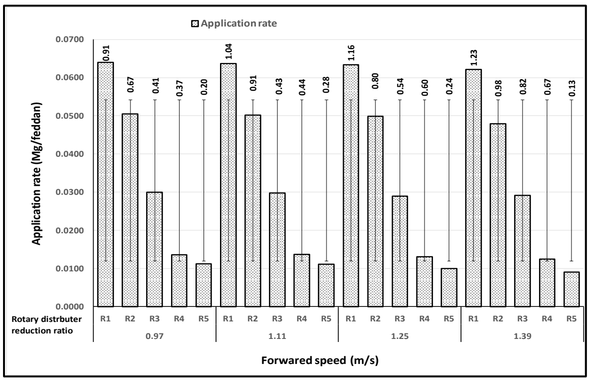


Fig. 11. Effect of rotary distributer speed at different planting forward speeds on fertilizer application rate

At reduction ratio R1, the application rate Mg/ feddan decreased by increasing the forward speed under fixed metering gate width 15 mm. By increasing the forward speed from 0.97 m/s to 1.11, 1.25, 1.39 m/s the performance rate was decreased by (0.47%, 1.09%, 2.97 %) while wheel skid increased from 0.64 % to 1.29, 1.55, 2.61 respectively. The results take the same trends at reduction ratios R2, R3, R4, and R5. The results indicated that the application rate is extremely effect by the slip ratio at different forward speeds. Also, the results indicated that the required application rate (0.028 Mg/ feddan) was achieved at reduction ratio R3, it was 0.0299, 0.0297, 0.0288, and 0.0291 Mg/ feddan at speeds of 0.97, 1.11, 1.25, and 1.39 m/s.

This means the modification can follow all forward speeds of the planter at the optimum adjustment of 15 mm gate width and reduction ratio between the land wheel and the rotary distributer 1:1.56. Also, the required application rate could be easy achieve by adjusting and calibrating the width of the dosing gate where the reduction ratio gives the rotary distributer a speed to make the granules enter to the cells of the distributer.

Machine field capacity (feddan/h)

The machine field capacity with the modification and without the modification, the results indicated that, there were differ between the field capacity before and after modification. The field capacity was 1.5, 1.67, 1.82, and 2.01 feddan/h at forward speeds 0.97, 1.11, 1.25, 1.39 m/s respectively. This means the modification did not effect on the planter performance.

Power requirements

The average fuel consumption of the machine was measured at forward speeds of (0.97, 1.11, 1.25, 1.39 m/s) it was (11.2, 11.9, 12.8, and 13.6 *l*/h) without load and reached with load to (15. 10, 16.9, 17.5, and 18.9*l*/h) respectively. The calculated power consumed for planting were (10.79, 13.84, 13.01, and 14.67kW.h) at the same speeds respectively.Also, the specific energy (kW. h / feddan) was 7.20, 8.29, 7.15 and 7.30 at forward speeds of (0.97, 1.11, 1.25, 1.39 m/s) respectively.

Modification cost analysis

The operating costs included fixed and variable costs were calculated for potato planting machine with modification and without modification. The total operating costs for the potato planting machine without modification was 568.5 EGP/h and 605.5 EGP/h with modification. Meanwhile, the same calculations were made for the tractor with price of 450000 EGP. The tractor cost per hour was 272.09 EGP/h. The cost of planting one feddan without modification was 312.3 EGP and 332.7 EGP with modification.

Economic feasibility of the potato planting machine

The total cost of the modified planting machine was 450000 EGP with 2019 price level. The reasonable rental value was 500 EGP/feddan (local market rental price). The planting machine indicated (NPV) of 41666.4 EGP at 14 % interest rate. Also, the planting machine payback period (PBP) was 3.1 year. On the other hand, the modification has indicated an add value due to increasing the potato yield by using such a modification. For two seasons in different two places, the cost of the one feddan of potato without using the modification and using the common fertilizers was 32912.3EGP/ feddan and it was 33132.7 EGP/ feddan with the modification. On the other hand, the potato yield in the experimental area with Spunta variety was 15.1 and 16.2 Mg/feddan with common fertilization and with nano fertilization respectively. This means that the modification success to add the required amount of fertilizer and added a value of 2199.6 EGP to each feddan profit.

CONCLUSION

- The metering unit succeeds to dose the required appellation rate of the nano fertilizer at all studied forward speeds of the belt bed planter without effecting on the performance of the planter.
- The Nano metering unit worked probably at the optimum adjustment of optimum adjustment of 15 mm gate width and reduction ratio between the land wheel and the rotary distributer of 1:1.56.
- The results indicated that the required application rate (0.028 Mg/feddan) was achieved at reduction ratio R3, it

was 0.0299, 0.0297, 0.0288, and 0.0291 Mg/feddan at speeds 0.97, 1.11, 1.25 and 1.39 m/s. This means the modification can follow all forward speeds of the planter at the optimum adjustment of 15 mm gate width and reduction ratio between the land wheel and the rotary distributer 1:1.56. Also, the required application rate could be easy achieve by adjusting and calibrating the width of the dosing gate where the reduction ratio gives the rotary distributer a speed to make the granules enter to the cells of the distributer.

-The modification did not effect on the planter performance. The field capacity before and after the modification was 1.5, 1.67, 1.82 and 2.01 feddan/h at forward speeds 0.97, 1.11, 1.25, 1.39 m/s respectively. The specific energy (kW. h/feddan) was 7.20, 8.29, 7.15, and 7.30 at forward speeds of (0.97, 1.11, 1.25, 1.39 m/s) respectively.

- The total operating costs for the potato planting machine without modification was 568.5 EGP/h and 605.5 EGP/h with modification.The cost of planting one feddan without modification was 312.3 EGP and 332. 7 EGP with modification.
- The planting machine indicated (NPV) of 41666.4 EGP at 14 % interest rate. Also, the planting machine payback period (PBP) was 3.1 year.
- Using such a potato planter with the modification increase the profit of the feddan. The potato yield in the experimental area with Spunta variety was 15.1 and 16.2 Mg/feddan with common fertilization and with nano fertilization respectively. This means the modification success to add the required amount of fertilizer and added a value of 2199.6 EGP to each feddan profit.

RECOMMENDATIONS

1. The modification can be manufactured locally to suit the requirement of the using nano fertilizers.
2. Providing such a potato planter with the new metering unit will be surely indicated an add value due to increasing the potato yield by using such a modification.

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جهاز لتلقيم الاسمده النانونيه مدمجه علي آله لزراعة البطاطس

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تم تعديل آله لزراعه البطاطس ذات سيور بنظام تلقيم ميكانيكي دقيق للاسمدة النانونية . يتكون نظام تغذيه السماد من عجلة أرض من الصلب تنقل الحركة إلى وحدة التلقيم عبر نظام نقل حركة مصمم للعمل تلقائيا دون التأثير على أداء آلة الزراعة ، وأجريت التجارب الحقلية بمنطقة النوبارية بمحافظة البحيرة بمصر. تم اختبار آله الزراعة المعدلة عند عرض فتحه بوابة لجهاز تلقيم السماد بخمسة أبعاد (5و10و15و20و 25 مم) ، وعند نسب تخفيض مختلفة بين عجلة الارض وموزع السماد الدوار عند أربع سرعات زراعة أمامية بلغت (0.97, 1.11, 1.25 , 1.39 متر/ ثانيه) . وقد أشارت النتائج إلى أن معدل الاضافة المطلوب (0.028 مجم / فدان) تم تحقيقة عند نسبة تخفيض للسرعة بين عجله الارض وموزع السماد الدوار (1: 1.56) حيث بلغ 0.0299 و0.0297 و 0.0288 و 0.0291 ميجاجرام / فدان عند سرعات أمامية 0.97 و1.11 و 1.25 و 1.39 متر/ ثانية علي الترتيب . وذلك يؤكد أن التعديل يناسب جميع السرعات الأمامية للزراعة عند الضبط الأمثل لعرض البوابة 15 مم ونسبة التخفيض بين عجلة الأرض والموزع الدوار 1: 1.56 ولم تتأثر السعة الحقلية بالتعديل حيث كانت السعة الحقلية قبل التعديل وبعده 1.5و1.67و1.82 و 2.01 فدان / ساعة عند سرعات أمامية 0.97.1.11 و 1.25 و 1.39 م/ ث على الترتيب . كما كانت الطاقة النوعية 7.20و8.29و7.15 و7.30 (كيلو وات . ساعه/ فدان) عند سرعات أمامية (0.97 و1.11 و 1.25 و1.39 متر/ ثانيه) على الترتيب. كما بلغت تكاليف التشغيل الكلية لآلة زراعة البطاطس بدون تعديل 568.5 جنيه/ ساعة و 605.5 جنيه/ ساعة بعد التعديل . وبلغت تكلفة زراعة فدان واحد بدون تعديل 312.3 جنيه مصري و 332.7 جنيه مصري بعد التعديل. وكان صافي القيمة الحالية 41666.4 جنيه عند سعر فائدة 14٪ . كما كانت فترة استرداد رأس المال لآلة الزراعة بالتعديل 3.1 سنوات. وأدي استخدام آلة زراعة البطاطس بعد التعديل الي زيادة ربح الفدان حيث بلغ متوسط إنتاجية البطاطس في منطقة التجربة مع صنف سبونتا 15.1ميجاجرام / فدان مع التسميد الاعتيادي و16.2 ميجاجرام / فدان مع استخدام تسميد نانو . ونجحت الآلة المعدلة بإضافة الكمية المطلوبة من السماد وإضافة قيمة ربح مقداره 2199.6 جنيه لكل فدان .