Effect of liquid poultry manure application rate and injection depth on growth and yield of maize (ZeamaysL.) in a sandy loam soil

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Abstract: Liquid poultry manure has long been recognized to be very desirable organic fertilizer. It improves soil fertility by adding both major and essential nutrients as well as soil organic matter which improve moisture and nutrient retention. Injection of liquid manure into soil can reduce nutrient loss through volatilization, reduce odor emission and surface runoff pollution, and increase plant uptake of nutrients. This paper reports the effectiveness of different levels of injected liquid poultry manure (LPM) on the growth and yield of maize (ZeamaysL.). The study was carried out at the Science and Technology Post-Basic (STEP-B) Research Farm of The Federal University of Technology, Akure, Ondo State, Nigeria during the rainy season in the year 2013. The experiment consisted of three treatments: control, 28 t/ha LPM and 56 t/ha LPM. The experiment was laid out in randomized complete block design with three replications. Maize ear diameter, ear length, number of kernel row per cob, number of kernel per row per ear, weight of 1000 kernels, and grain yield were significantly affected by application of LPM. Maximum values for all these parameters were recorded with the application of 56 t/ha LPM. The highest rate of liquid poultry manure (LPM) application (56 t/ha) improved maize yield by 64.8% over the control while the lowest rate of LPM application (28 t/ha) improved maize yield by 62.5% over the control.

Keywords: Injection, liquid poultry manure, maize (ZeamaysL.), growth, yield

Citation: Manuwa, S. I., O. C. Ademosun, and L. O. Akande. 2015. Effect of liquid poultry manure application rate and injection depth on growth and yield of maize (ZeamaysL.) in a sandy loam soil. AgricEngInt: CIGR Journal, 17(1): 1-9.

1 Introduction

Maize is an important cereal crop that provides staple food to large number of people across the globe and is a major source of income to many farmers in developing countries (Tagneet al., 2008). Maize is a relativelyshort duration crop and capable of utilizing inputs to produce a large quantity of food grains per unit area. Efforts aimed at obtaining high yield of maize would necessitate the augmentation of the nutrient status of the soil to meet the crop's requirements for optimum productivity and maintain soil fertility. Increasing the nutrient status of the soil may be achieved by boosting the soil nutrient content either with the use of inorganic fertilizers such as nitrogen, phosphorus and potassium or through the use of organic materials such as poultry manure, farm yard manure or the use of compost. The maize crop requires an adequate supply of nutrients particularly nitrogen, phosphorus and potassium for optimum growth and yield. The most important micronutrients are sulphur, zinc and magnesium (Iken and Amusa, 2004).

Organic fertilizers including farmyard manure, sheep manure and poultry manure may be used for the crop production as a substitute for chemical fertilizers (Agbaet al., 2012). Worldwide, there is growing interest in the use of organic manures due to depletion in the soil fertility. Synthesis of chemical fertilizers consumes a large amount

Received date: 2014-01-08 **Accepted date:** 2015-01-12
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of energy and money. However, an organic farming without chemical fertilizers seems to be a possible solution for these situations (Prabuet al.,2003). Inorganic fertilizer is expensive and may be largely unaffordable and not available to the resource-poor farmers in Nigeria. On the other hand, organic manure such as poultry manure is readily available as inexpensive source of nitrogen for sustainable crop production.

Poultry manure had been reported to improve growth and yield of maize relative to no fertilizer (Adeniyan, and Ojeniyi, 2005; Ezeibekweet al., 2009) and improves the chemical and biological qualities of the soil which increases crop productivity relative to chemical fertilizers (Obi and Ebo, 1995). Poultry manure application registered over 53% increases of N level in the soil, from 0.09% to 0.14% and exchangeable cations increase with manure application (Boatenget al., 2006). In agriculture, the main reasons for applying poultry manure include organic amendment of the soil and provision of nutrients to crops (Warrenet al., 2006). Nigeria's livestock population annual growth rate is 3.2% (Adelekanet al., 2010), hence large quantities of livestock manure is virtually assured in Nigeria for years to come along with their associated demerits (Adelekanet al., 2010). In Nigeria, about 932.5 metric tonnes (MT) of manure is produced annually from the well-established poultry/livestock industries which expand at an annual rate of 8%(Adewumiet al., 2011). Adewumi and Adewumi (1996) reported that a layer produced an average of 161 g of manure per bird per day. This large turnout of wastes from poultry, swine production, cattle rearing etc. encourages the growth of microbes, attracts houseflies, constitutes a health hazard to humans and animals and thus becomes a menace to the environment. Options have to be investigated to turn manure into a more useful resource rather than being a mere pollutant which further burdens agriculture and the environment.

Land application of liquid manure has been recognized as a cost-effective and sustainable practice for manure utilization. Comparable or higher crop yields can be achieved when using liquid manure to replace chemical fertilizers (Chen and Tessier, 2001). In the past, surface application has been the most common method used for spreading liquid manure. Farmers in Nigeria commonly apply cattle dung through broadcasting on the soil surface (Gana, 2011). According to Gana, this method is inexpensive, cheap, simple and easy, and does not require the use of any special equipment. This practice results in loss of nutrients in surface runoff water, significant odor emissions and nutrient losses mainly through ammonia volatilization. One method that can minimize these problems is injection where manure is placed below the soil surface and covered with a layer of soil. Moseley et al. (1998) reported better performance of sweep-type injection tools in terms of mixing manure with soil. Adequately mixing manure with soil can minimize denitrificationcaused nutrient losses (Jokela and Cote, 1994) and promote aerobic stabilization of the manure (Negiet al., 1978). Since sweeps can create relatively larger cavities in soil that can contain large amount of injected manure, they are also suitable for manure injection at high application rates (Chen and Tessier, 2001). However, there are certain risks of plant macronutrients accumulation in the soil and their subsequent losses to the underground water or to surface water reservoirs (Theodora, 2003).

Ketteringset al. (2013) evaluated the impact of manure application rate (84,000, 112,000 and 140,000 L/ha). They determined that an increase in manure rate beyond the 84,000 L/ha did not increase yield. Information is presently scarce on the injection of liquid poultry manure in soil as fertilizer in Nigeria. The main objective of this study was to evaluate the effect of liquid poultry manure and injection depth on growth and yield of maize in a sandy loam soil.

2 Materials and methods

A field experiment was conducted at the Science and Technology Post-Basic (STEP-B) Research Farm of The Federal University of Technology, Akure, Ondo State, Nigeria. It is on longitude 7°15′N and latitude 5° 15′ E on an elevation of 210 m. Materials used for this experiment included manure injection equipment, machet and hoe, liquid poultry manure as fertilizer, maize, digital micro-meter screw gauge, digital moisture meter, cone penetrometer and soil moisture meter. Manure was obtained from layer pen of the Federal University of Technology, Akure Poultry Farm on May 1, 2013. A solid-liquid separation process was conducted. This is a settling of particles of specific gravity greater than one (Zhang and Westerman, 1997), and this could clog the manure discharging point during manure injection. A screen with openings of 1mm was then used to remove particles bigger than the openings in the screen from the slurry.

2.1 Equipment description

Injection-unitfield equipment was formed by two injection tools mounted on a pull-type, 2 m wide implement frame. A lateral tool spacing of 60 mm was selected based on the conclusion drawn by Warner and Godwin (1988) that tool spacing smaller than 65mm was suggested for uniform crop response. The flow control points hadtwo gauge valves and arcs that determined the degree of their turning. The flow was manually adjusted from 90° to 0° to obtain nine different settings for different liquid manure flow rates. The valves werefully opened at 90° and fully closed at 0°. Calibrations of manure flow rate from the tank were performed with the injection tools raised above the soil surface. During the calibration, the pump was run for 30 seconds at each of fivesettings (10°,30°,50°,70°,90°). A 0.20 m^3 plastic bucket was used to collect the manure which flowed out of each injection tool while the pump of the tank was operating at each of two gate-opening settings.The average manure volume in the 0.20m^3 plastic buckets and the time for filling the buckets were used to determine the relationship between gate–opening setting (gauge valve) and the manure flow rate. This relationship was used in the field experiment for selecting the gate–opening setting to obtain the desired manure application rates (28 and 56 m^3/ha) at a given injector travel speed (0.97 m/s or 3.49km/h).The pipe network installed on the frame featureda100mm PVC hose which received manure from the pump anddistributedthe manure to each of the twoinjectiontools through flexible 50 mmPVChoses.Thehoses were fitted insidethemanure-delivery-tubes which were made of 75 mmdiameter galvanized steel pipe. The injection equipment (Figure 1) was pulled by a 415 MF tractor during the experiment. The soil of the experimental plot was tilled at a greater depth than the maximum experimental design depth before the experiment.

Figure 1 Liquid manure injector equipment

2.2 Details of experimental designs, and treatments

A (2 × 3) randomized complete block experimental design with three replications was conducted. The experiment investigated the maize yield as affected by quantity of liquid layer manure injected in the field before planting. Plots were laid out in parallel with each plot measuring 10 × 3 m with 50 and 100 cm paths separating adjacent plots and blocks respectively.Treatments and levels were represented by Q_i and D_i respectively, where, Q_i (i= 1, 2, 3) and D_i (i= 1, 2, 3).Two manure application rates: Q_1 = 28 t/ha (23000 L/ha) which contains total nitrogen (33.6 kg), phosphorous (0.84 kg), potassium (19.6 kg), sodium (7.8 kg); Q_2 = 56 t/ha (46000 L/ha) which contains total nitrogen (67.2 kg), phosphorous (1.68 kg), potassium (39.2 kg), sodium (15.6kg) and at three target injection depths (D_1= 50, D_2 = 100 and D_3 = 150mm) were used during the experiment. The injection equipment rake-angle was set at 30^o. A low travel speed of (3.49 km/h) was used.The maize plant stem diameter, number of leaves per plant and plant height were assessed between threeandeleven weeks after planting. Also, the maize yield traits were evaluated after harvesting.

2.3 Soil preparation, measurements and agronomic practice

The field had a sandy loam (11.5% clay, 24% silt and 64.5% sand, by weight) with 200mm high cereal stubble. The field was ploughed below maximum experimental depth (150 mm) before the experiment using a disc plough. The soil dry bulk density of 1.79 mg/m^3 and moisture content of 25% wet basis at the time of the field experiment. Also, soil strength (10.6 kPa) was measured using a soil cone penetrometer (Rimik model CP40II, RFM Australia Pty Ltd, Toowoomba QLD 4350, Australia) with 12.83 mm cone base diameter and 30^o angle based on ASAE standard (ASAE, 1995).The penetrometer was pressed into the soil at a rate less than 10 mm/s to measure the cone index which was observed on a digital readout.

The experimental field was ploughed on May 1, 2013 and harrowed on May 10. The first treatment of manure (28 t/ha) was injected in the field on May 12, 2013. Also, the second liquid manure treatment (56 t/ha) was injected on May 14, 2013. The equipment was run dry (0 t/ha LPM) on the control plots at three depths (50, 100 and 150 mm). A hybrid maize variety (Swam 1) obtained from the seed multiplication units of the Agricultural Development Project (ADP), Akure, Ondo State and also from the Federal University of Technology, Akure, Research Farm was used as the test crop. Three maize seeds were sown per hill on May 16, 2013 and later thinned to two seedlings/hill at a spacing of 75 × 30cm. The plant population was 88,000 plants per hectare. Weeding was done manually at 3, 6, and 9 weeks after planting. Fifteen maize plants in the middle of a row were used as sample population for data collection. At maturity (105 days after planting), the maize were harvested, the ears were dried for 10 days, and yield parameters were determined. Table 1 shows the weather data of the experimental site during the experiment.

Table 1 Average monthly weather data at the experimental site during the 2013 growing seasons

Month	Temperature (^{o}C)				Rainfall (mm)	
	Average		Absolute			
	Max	Min	Max	Min	Daily	Monthly
April	10.1	8.1	39.2	12.2	1.6	48
May	6.2	5.4	33.3	15.7	2.3	69
June	7.3	6.2	32.5	20.2	2.0	60
July	10.4	9.8	39.0	9.5	2.0	60
August	11.0	6.1	30.1	17.9	5.1	153

2.4 Statistical analysis

All data collected were statistically analyzed using T-tests and Duncan's multiple range tests (DMRT) using SPSS version 17statistical software (IBM Corporation) at 0.05 probability levels.

3 Results and discussions

The results of this study showed that the application of different quantities of liquid poultry manure significantly improved the growth and yield of the 'Swam 1' cultivar of maize. The performance of the maize grown with LPM during the 2013 season was better than where poultry manure was not applied (control).

3.1 Maize plant height

The height of maize plants was significantly different at a 5% significance level among the rates of liquid poultry manure applied (data not shown). Maize plant heightduring the growing season is shown in Figure 2. Weekly plant height increased proportionally to the quantity of LPM injected in all the plots. The highest plant height (234.6 cm) was recorded at locations where 56 t/ha LPM was injected at the 100 mm depth (Q_2D_2). The least plant height (160.9 cm) was found in the control plot where no manure was injected. The results revealed that LPM has influence on maize plant height.

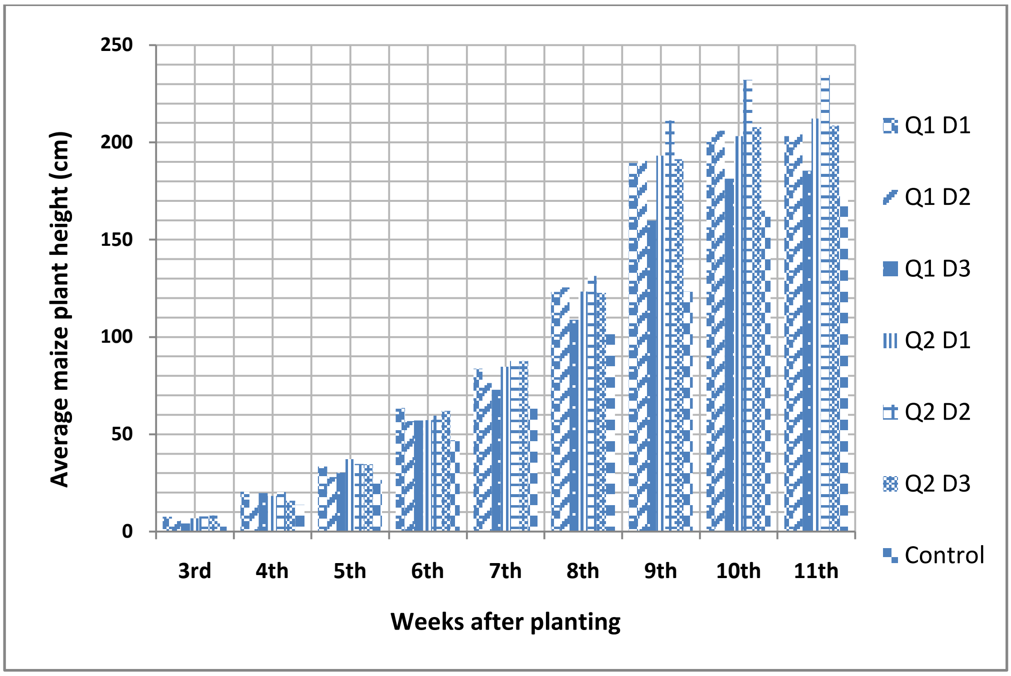

Figure 2Average height of maize plants as a function of time after planting

3.2 Maize plant stem diameter

It was observed from the results that LPM enhanced vigorous maize plant stem girth. The maize plant stem girth increased every week in all the plots. The highest maize plant stem girth (32.03 mm) was found in the plot receiving 56 t/ha LPM at an injection depth of 100 mm (Q_2D_2) while the least plant stem girth (23.39 mm) was found in the control plot.This result indicated that LPM has influence on maize plant stem girth development. This result is in agreement with Okoruwa (1998). Figure 3 shows maize plant stem girth growth weekly.

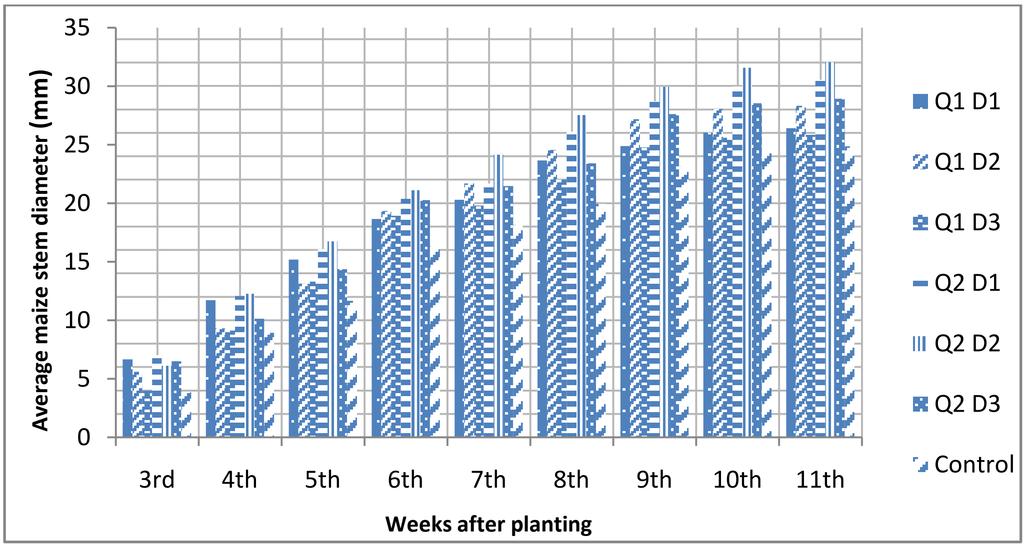

Figure 3Weekly maize plant stem diameter

3.3 Number of leaves per maize plant

The number of leaves produced differed significantly among the rates of poultry manure and the depth at which the LPM was injected (Figure 4). Application of LPM at 56 t/ha produced higher number of leaves (17 leaves per plant) compared with application of 28 t/ha of LPM which produced 16 leaves

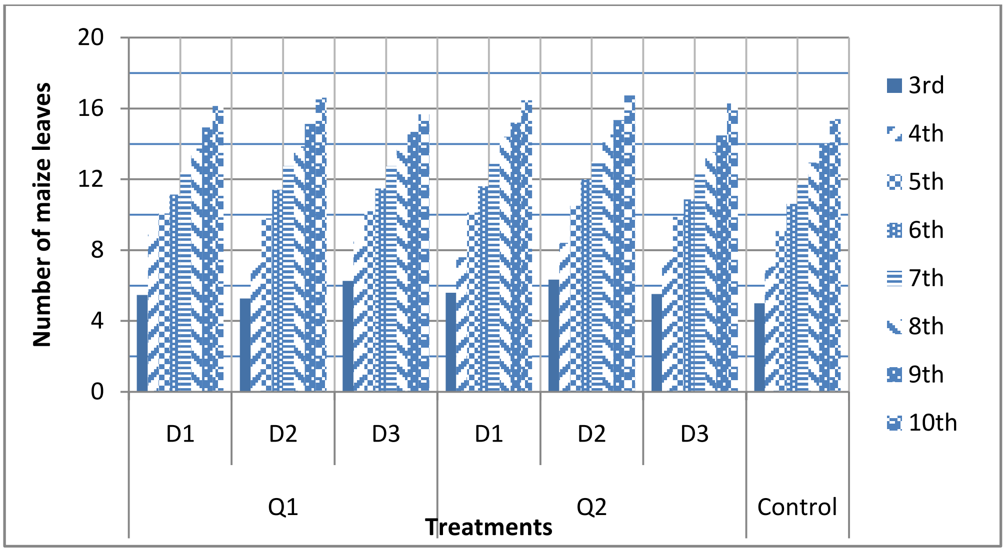

Figure 4Number of leaves per maize plant (WAP: weeks after planting)

Per plant and the control where LPM was not applied produced 15 leaves per plant. These results agreed well with the findings of Adelekanet al.(2010), and Agbaet al. (2012).

3.4 Maize ear diameter

Maize ear diameters were analyzed at 5% significance level of the difference between the means of 24 pairs. Maize ear diameter increased relative to amount of LPM injected. The highest average ear diameter (5.13 cm) was recorded in the plot treated with 56 t/ha LPM at 100 mm depth (data not shown) and the least maize ear diameter (4.67 cm) occurred for the control plots. The observed significant performance in maize ear diameter with the application of LPM could be attributed to the essential nutrient elements contained in the poultry manure that are associated with increased photo-synthetic efficiency of the maize (Daudaet al., 2008).

3.5 Maize ear length

Maize ear lengths were analyzed for a 5% significance level of the difference between the mean. The highest maize ear length (18.6 cm) occurred for the 56 t/ha LPM treatment and the least occurred for the control (13.13 cm) where LPM was not applied (data not shown).

3.6 Average number of kernel rows per ear

The results of number of kernel rows per ear were analyzed at 5% significance level of the difference between the mean. The number of kernel row increased proportionally to quantity of LPM injected.The highest results were in order of 56 t/ha LPM (17 kernel rows) 28 t/ha LPM (15 kernel rows), while the control brought out 15 kernel rows per ear. The increase in number of kernel rows per ear was attributed to the LPM application rates of 56 and 28 t/ha which increased nutrient availability throughout the growing period. These results are similar to the findings of Zhang et al.(1998) and Agbaet al. (2012) who reported that precise application of manure to maize crop can be as effective as commercial N fertilizer for maize yield response.

3.7 Number of kernels per row in ear

The number of maize kernels per row in ear was analyzed at 5% level of significance.The number of kernels per row is also an important parameter contributing towards the final maize yield. The maximum number of kernel per row on the ear for the three treatments of liquid manure (56, 28, and 0 t/ha) were 41, 38 and 30, respectively.It is not clear whether the increase in number of kernels per row may be attributed to the availability of more nitrogen and other nutrients from LPM required for maize plant development up to ear formation.

3.8 Weight of 1000 kernels

The mass of 1000 kernels was analyzed using the t-test statistic to compare 24 pairs. The mass of 1000 kernels are in order Q_1D_1 (243.15g), Q_1D_2 (262.97g), Q_1D_3 (246.60g), Q_2D_1 (256.82g), Q_2D_2 (274.23g), Q_2D_3 (250.70g). The 1000-kernels mass increased significantly with each progressive increase in LPM rate and was greatest (274.23g) at 56 t/ha.The thousand kernel mass was in the order 56 t/ha > 28 t/ha >control. These results are in accordance with the findings of Ma et al.(1999) and Garg and Bahla (2008). The increase in 1000- kernel mass with increased level of LPM could be due to balanced supply of food nutrients from liquid poultry manure throughout development of the maize plant.

3.9 Grain yield

The mean maize kernel yield of 2.64, 2.48 and 0.93 t/ha were obtained from the use of 56, 28 and 0 t/ha LPM respectively. The results indicate that LPM at the rate of 56 and 28 t/ha have the potential to improve maize yields significantly over control. The highest rate of liquid poultry manure (LPM) application (56 t/ha) improved yield by 64.8% over the control while the lowest rate of LPM application (28 t/ha) improved yield by 62.5% over the control. Grain yield increased proportionally with rate of manure application. Yield increases were significantly different among treatments (Table 2). ANOVA results show that the interactions of various treatments were significantly different ($P < 0.05$) according to Duncan's multiple range tests (DMRT).

Table 2Mean grain yield (t/ha) for the various combinations of liquid manure application rate and manure injection depth

Liquid poultry manure application rate (t/ha)	Depth of injection (mm)		
	D_1 (50 mm)	D_2 (100 mm)	D_3 (mm)
	50	**100**	**150**
0	0.77a	0.93b	0.95c
28	2.47b	2.50c	2.45a
56	2.55c	2.66a	2.49b

Note: *Means in the same column that are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range tests.

Twenty-eight and 56 t/ha level of LPM application produced an appreciable maize grain yield of 2.48 and 2.64 t/ha respectively which is within the global average yield of 2.2-3.5 t/ha (Olaoye and Adegbesen, 1991). The highest grain yield obtained in this research with 56 t/ha LPM application is much higher than the average grain yield of 1 t/ha usually reported for West African farmers. Without the application of LPM, the average maize kernel yield from this research was 0.93 t/ha which is close to the yields generally obtained by farmers who are not able to afford the use of fertilizers in this agro-ecological zone.

4 Conclusions and recommendations

The study shows that LPM is a valuable organic fertilizer that can be used as an alternative to inorganic fertilizer in maize production and soil fertility.Yield of maize was significantly increased over that of the control albeit at high application rates of 28 and 56 t/ha.With the present high cost of mineral fertilizer (in Nigeria), which is largely unaffordable and unavailable to many farmers, the yield potential by farmers in using LPM can be can be realized by using LPM. An application rate of 56 t/ha increased yields by more than 64.7% over the control.It is recommended that 28 t/ha application rate is more efficient considering yield perspective, while 56 t/ha application rate is justified for waste reuse.

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