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Performance of Single Spinning-Disk Type Solid Manure Spreader

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Abstract: In this research prototype of single spinning-disk type solid manure spreader that not just manufactured in Turkey was manufactured and its power take off requirement, fuel consumption and distribution uniformity at different feed velocity with two kind of manure was investigated.
Two kind of manure as separated and fresh were used in tests and the test were conducted at three different feed rate (q_1:4, q_2:6 ve q_3:8 kg/s) and two different vane position of the single spinning - disc (K_1: Radial, K_2: 17^o forward).
It was found that the parameters which were considered on the tests have significant effects ($P<0.01$) on coefficient of distribution variation, power take off requirements and fuel consumption. The minimum variation coefficient, effective working width, fuel consumption and power take off requirement were varied as 5.61-54.64%, 5.5-8 m, 6.59 – 12.23 l/h and 5.09 – 7.36 HP regarding with working conditions.
Key words: Farm manure, solid manure spreader, distribution uniformity

Tek Diskli Tip Ahır Gübresi Dağıtıcısının Performansı

Özet: Bu çalışmada ülkemizde üretimi henüz yapılmayan diskli tip bir ahır gübresi dağıtma makinasının prototipi yapılarak, makinenin farklı besleme hızları ve iki ayrı gübrenin dağıtımındaki kuyruk mili gücü gereksinimleri, yakıt tüketimleri ve dağılım düzgünlükleri araştırılmıştır.
Denemelerde taze ve seperatörden ayrıştırılmış olmak üzere iki farklı özelliklere sahip ahır gübresi kullanılmıştır. Denemeler üç farklı besleme yoğunluğunda (q_1:4, q_2:6 ve q_3:8 kg/s) ve diskin 2 farklı kanat konumunda (K_1: Radyal, K_2: 17^o ileri) yürütülmüştür.
Genel olarak sonuçlar incelendiğinde, denemede ele alınan parametrelerin, dağılımın varyasyon katsayısı, kuyruk mili gücü gereksinimi ve yakıt tüketimi üzerindeki etkisinin önemli olduğu görülmüştür ($P<0.01$). Çalışma şekline bağlı olarak dağılımın minimum varyasyon katsayısı % 5.61-54.64, efektif iş genişliği 5.5-8 m, makinenin yakıt tüketiminin 6.59 – 12.23 l/h ve makinanın kuyruk mili gücü 5.09 – 7.36 BG arasında değiştiği belirlenmiştir.
Anahtar kelimeler: Ahır gübresi, ahır gübresi dağıtıcısı, dağılım düzgünlüğü

INTRODUCTION

Great part of Turkey land is poor and insufficient in terms of organic material. Especially, organic material level of middle – Anatolian's land are less than 1%. The levels of organic material content are tried to increase mixing different organic materials to agriculture land. Farm manure is the most used solution because of it's simple application and (great amount) abundancy. Farm manure is a kind of fertilizer which provides versatile advantage in terms of organic material and wide microorganism enclosure.

The effect of farm manure to properties of soil is to increase water holding capacity, to restrain runoff and evaporation. Also it provide protection against water and wind erosion by fixing soil particles, provide getting best time of soil preparation, to make easier soil cultivation and provides best soil temperature for plants. Commercial nitrogenous fertilizers (especially ammonium nitrate fertilizer) leaches because of irrigation and rain. On the other hand, farm manure forms consist of organic small residuals, so it includes all nutrition elements (nitrogen, phosphorus, potassium, calcium, magnesium, and micro elements) and it is the sustainable source of nitrogen which is the most important nutrition for plants.

Farm manure has an important (growing) potential as depending on animal production. But farm manure isn't used commonly in Turkey because

of storing cost and separating costs to field, requirement of labour force and especially in rural region it is used as a fuel.

Considerable yield increases were obtained by using chemical fertilizer as known "Green Revolution" happen in 1970's. However this fertilizer lost importance due to damaging to soil structure, yield decreases and environmental problems.

The total use of chemical fertilizers are 5.488.000 tones in Turkey (Anonymous, 2007). The chemical fertilizer consumption costs 2.5 billion $ per year. If the only annual cattle manure is used in agriculture, requirement of chemical fertilizer would be met 65%. If the half of the annual cattle manure was used in agriculture it would contribute 810 billion $ to the economy of country.

When number of cattle in our country is considired (11.147.438 number), it can be obtained approximately 450.000 tone farm manure daily (Anonymous, 2001). 290 thousand tones of this manure are liquid and 160 thousand tones are solid. Today, especially liquid manure goes to rivers and are wasted without benefiting. As a result of this situation, environment and water pollution occur. In recent years, both in the world and in our country sustainable agriculture becomes a current issue with the aim of protecting natural ecosystem which is more sensitive.

In our country the number of manufacturer farm manure spreader is highly limited. While in 1997, the numbers of these machines are approximately 1680, after 10 years it reaches 1950 with 16% increments. Most of the machines available which are importation are over 10 years.

The rapid increment of the number milk farming increases with a high rate as a result of incitement in recent years. This situation is causing many problems to the managing to utilize of liquid and solid manure, with a other expression to spread the field because of insufficient machine number.

The machine speed and spreader type and the structure of spread manure, peripheral speed of spreader beater and the speed of feed all affect spreading uniformity of machine. It is explained that in spreader with horizontal beater to spreader with vertical beater, working wide is smaller and it provides distribution uniformity. It is stated that, in evaluation of distribution uniformity, making average deviation values can be 10-30% in different distribution level and depending on the speed of feed, the total power can change from 22 to 56 BG (Kasap, 1983).

The success of horizontal beater spreading manure depends on type of manure and the height carrying spreader wings. This height has an important affect on the movement of has breaking members in a certain time. To prevent the disorderness while distributing, it is stated that, it must be charged to spreader from with to its height, and it shouldn't passed over the height of element carrying the height of manure to spreader wings.

Hanna et al. (2004), as a result of their experiment with two different solid manure machines which have a spreader beater at the back and sides, stated that the size of manure's grain is important for the design of favorable equipment. The process of homogeneous distribution cannot be applied because the pieces of manure in different size follow different orbit while spreading.

Kasap (1983), found that the torque requirement are in order 38-65,5 daNm and 30,4-79,1 daNm in auger and peg type solid manure spreader. Better distribution uniformity is obtained in peg type solid manure in comparison to spiral type solid manure when the speed of feed (norm of manure) increases, the distribution uniformity increases too. Better distribution uniformity is obtained as CV of 14,3% in peg type manure spreader.

Norman-Han et al. (2008), emphasized on the breadthways and longitudinal distribution uniformity of manure spreader with back and side. Distribution uniformity of manure spreader with back and side distribution uniformity of spreader machines from its side are in order breadthways and longitudinal 59 % and 53% in the spreader machine with back; this value was determined as 107% and 72%. It is was found that single and double horizontal beater type spreader from with back gives similar distribution uniformity.

Landry et al. (2005), researched to evaluate the performances of different conveying systems for manure spreaders and to study the effect of the geometry of the holding system on material flow. A prototype spreader was evaluated with both a scraper conveyor and a system of four augers. The specific

energy required to unload the machine with the 4-auger system was found to be higher than with the scraper conveyor, with average values for all experimental runs of 184 J/kg and 73 J/kg, respectively. The specific energy for both conveying systems was found to be significantly affected by the position of the gate. The 4-auger system seemed to perform better than the scraper conveyor, with an average value of longitudinal CV of 58% compared to 75% for all the experimental runs.

Distribution of manure in different height causes falling in different distribution distance. In addition, at the time of turning manure from the body, floor of manure is 15-25% down from average value. About end of discharging, this value 12-20% over of average 50 it is explained that distribution of manure from the body isn't uniformly (Önal, 1987).

Boz (2008) in his working with solid manure spreader with horizontal and vertical beater, stated that spreader with horizontal beater provider better distribution uniformity. And, he also stated that the volume height and particle greatness of the manure which will be spread is effective on distribution uniformity and bound to increasing peripheral speed of beater, distribution uniformity is damage. Because of not getting symmetrical distribution in all working combination, it is stated that returning working (CV of average 20,73%) method is more suitable instead of forward-back method. (CV of average 39,12%).

In this study, the prototype of a solid manure spreader machine which isn't just invented before is tone that different feed speed of machine and the requirement of tail spindle power in different two manure distribution, consumption of fuel and distribution uniformity are found.

MATERIAL and METHOD

In the study, the prototype of a solid manure spreader machine was produced which hasn't been manufactured yet in our country. Machine was produced in faculty workshop and industry of Konya. It is given some properties of machines in Table 1 and it is given general view in Figure 1.

The solid manure with 2 different properties are used which is fresh and separated. it is given some physico-mechanics properties in Table 2. To measure shearing tensile of manure, the cutting apparatus with wing is used and to determine static friction coefficient, inclined plane with sheet metal plate is used (Landry et al. 2004; Landry, 2005).

Table 1. Some structural properties of the machine.

The measurement of manure holding system:	
Holding system capacity (m^3)	4.62
Holding system cross-sectional area (m^2)	1.42
Holding system height (mm)	1000
Ceiling width of holding system (mm)	1760
Floor width of holding system (mm)	1000
Cross – sectional brim measurement (mm)	1000x380
Conveyor measurement:	
Rasp bar measurement (mm)	NPU 4
Rasp bar space (mm)	500
Spreader measurement:	
Disk diameter (mm)	1050
Disk peripheral speed (m/s)	51.25
Height of disk from the ground (mm)	700
The number of wing (piece)	4
Wing measurement (mm)	420x60
Feed radius of disk (mm)	150

Table 2. Some physico-mechanics properties of used manure

	Fresh manure (G_1)	Separated manure (G_2)
Bulk density (ton/m^3)	1,016	0,374
Angel of repose (°)	41	32
Shearing stress (N/cm^2)	0,332	0,083
Static coefficient of friction (on the steel plane)	0,808 (39°)	0,758 (37°)
Moisture (%)	78	36

The tests were conducted in 3 different feed rate (q_1:4, q_2:6 and q_3:8 kg/s). The speed of manure conveyor is changed to get same feed rate in two different manure (driven gear diameter). In the study, 2 different wings position (K_1: Radial, K_2:17° forward) is used. The clearance of manure feeding has an importance on both power consumption and distribution uniformity. So, it is fixed in all combinations. The working speed of machine is 4,5 km/h in the study.

Figure 1. The general view of the machine in the test

The measurement device of fuel consumption mark of Aqua Metro is used which can measure with 1 ml sensitiveness in the definition of fuel consumption. The measurement device of torque requirement of machine mark of Digitech power take of torquemeter with 2000 Nm capacity is used in the definition of. The signals taking form in torquemeter is transferred to datalogger. The mark of Muntil-PRO datalogger which information, with graphic, with collecting information, with analysis system and tunable of data space is used in the definition of data. Steyr-768 tractor is used in the experiment.

It is benefited from the boxes of sheet iron collecting which is 500x500x170 mm measurement in the collecting of spread manure (Anonymous, 2004). After each 3 transition on the box with tractor, accumulated manure in the box is weighed with electronic weighing machine with 0,01g sensitiveness. Benefiting from quantity of spread manure, distribution graph design is drawn on the computer and average deviation is given as percentage. Distribution design multiplies as width of a box each time in the evaluation of results. Coefficient of variation (CV%) getting after each folding and working width and working width variation are calculated by a special programme on the computer for forward-back and turning working type. The upper limit of distribution uniformity which is acceptable is taken as CV of ≤30% percent value (Anonymous, 2004). The values of coefficient of variation of distribution design belonging to forward-back working method are applied variance analysis and the test of LSD.

RESULT and DISCISSION

In Figure 2 and 3 it is given three different feeding intensity with two different solid manure and distribution design getting at the end of experiments in the position of two wings.

It is given Table 3 that the proportion of manure throwing to the left and right side of distribution design and minimum variation coefficient for forward-back an turning working type with Exchange border.

Bound to working type minimum variation coefficient of distribution changes between 5,61-54,64 percent. And, effective working width changes between 5,5-8 m.

When taking into consideration, percent manure proportion throwing right and left side of the machine parsed manure from separator is 3,5 percent more than the quantity of manure throwing right side. Being lower of the separated manure in the spreader than the fresh manure in terms of static friction coefficient and cutting tensile causes early leaving of manure from disc. This situation effects negatively the symmetry of distribution design.

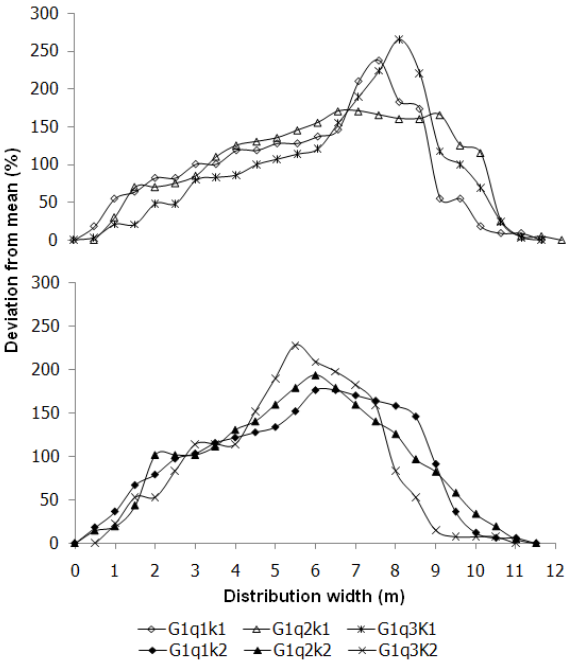

Figure 2. Distribution design getting 3 different feed rate with fresh manure

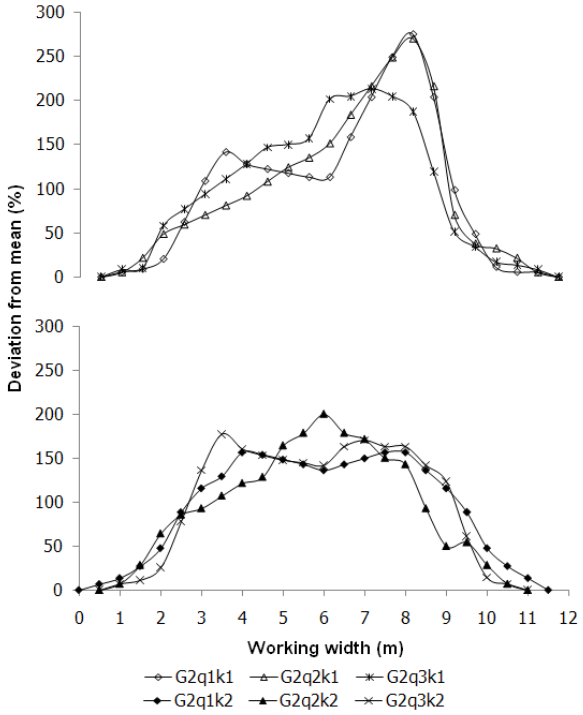

Figure 3. Distribution design getting 3 different feed rates with manure parsed from separator

Because of being irregular distribution symmetry in the separated manure than fresh manure, the average minimum coefficient of variation depend on folding type is 29,46% in forward – back working. But in the fresh manure, it is 25,99%. The average minimum coefficient of variation is 27,72% in forward – back working for each two manures. But in turning working it is 20,35%. On the condition that being not symmetry, it is got better distribution in the turning working type. The results of variance analyses show that the effect of manure type on coefficient of variation of distribution is significant ($P<0.01$) (Table 4).

Depend on increasing feed rate, the coefficient of variation of distribution decreases on the other hand, it is seem that distribution is getting better two times increase in feed rate causes 4% progress of distribution. Similar results are obtained by also Kasap (1983) and Boz (2008). It is found that the effect of the changing of feed rate on minimum coefficient of variation is significant ($P<0.01$) (Table 4).

To be changed of wing position from radial to forward increases distribution uniformity. It is seen that left side spread manure quantity increases because remaining period of manure on the disc increases at the forward wing position. This situation, increases distribution symmetry according to radial wing position and it causes 63% decrease at minimum coefficient of variation of distribution. It is obtained that the effect of changing of wing position on coefficient of variation is significant ($P<0.01$) (Table 4).

It is found that fuel consumption of the machine changes between 6.59 – 12.23 l/h (Figure 4). The average fuel consumption of fresh manure with high bulk density and shearing stress is 10.01 l/h. But it is 8.94 l/h in separated manure with 10% decrease. Depend on increasing feed rate, the values of fuel consumption increase. 100% increase in feed rate provides 63% increase of fuel consumption. It is found significant the effect of the manure type and feed rate on fuel consumption ($P<0.01$) (Table 5).

Table 3. Minimum coefficient of variation, effective working width and changing limits of the machine taking to test in the best combination

Combination type	$\%\frac{Left}{Right}$ Spread quantity	Minimum coefficient of variation (%)		Effective working width (m)		Changing limits of working width (m)	
		FB	T	FB	T	FB	T
$G_1q_1K_1$	41,44/58,56	34,41	30,05	-	-	-	-
$G_1q_1K_2$	47.72/52,28	12,86	18,68	6,5	7,5	5,5…8	5.5…9
$G_1q_2K_1$	40,71/59,29	30,06	20,61	-	7	-	6…9
$G_1q_2K_2$	50,22/49,78	10,23	10,17	5,5	5,5	5,5…8,5	5,5…9
$G_1q_3K_1$	32,29/67,71	54,64	34,42	-	-	-	-
$G_1q_3K_2$	51,12/48,88	14,23	17,46	5,5	5,5	5,5…6,5	5,5…7,5
$G_2q_1K_1$	37,63/62,37	47,57	32,88	-	-	-	-
$G_2q_1K_2$	46,82/53,18	15,5	5,61	7,5	7,5	5,5…9	5,5…9
$G_2q_2K_1$	33,91/66,09	54,35	37,08	-	-	-	-
$G_2q_2K_2$	44,54/55,46	19,20	9,84	6,5	5,5	5,5…8	5,5…8,5
$G_2q_3K_1$	42,81/57,19	23,46	19,18	5,5	6	5,5…7	5,5…7,5
$G_2q_3K_2$	47,39/52,61	16,72	8,32	7	7	6…8	5,5…8

Table 4. The result of variance analyses and the test of LSD which is done over the value of minimum coefficient of variation of distribution uniformity

V.S.	D.F.	M.S.	F	Manue	Feed rate	Wing Position
Manure (G)	1	72.24	1050.84**	G_1 25.99$_a$	q_1 28.34$_a$	K_1 40.67$_a$
Feed rate (q)	2	2.48	36.12**	G_2 29.46$_b$	q_2 27.58$_b$	K_2 14.79$_b$
Wing position (K)	2	4019.68	58468**		q_3 27.26$_c$	
G*q	2	516.15	7507.74**	LSD(%5): 0.23	0.28	0.23
G*K	1	9.07	132.03**			
q*K	2	8.09	117.76**			
G*q*K	2	368.71	5363.19**			
Error	12	0.06				
Total	23	256.20				

Table 5. The result of variance analyses and the test of LSD which is done on the value of fuel concumption

V.S.	D.F.	M.S.	F	Manue	Feed rate
Manure (G)	1	3.43	171.13**	G_1 10.01 $_a$	q_1 7.13 $_a$
Feed rate (q)	2	20.10	1005.33**	G_2 8.94 $_b$	q_2 9.72 $_b$
G*q	2	0.04	2.10ns		q_3 11.59 $_c$
Error	6	0.02		LSD(%5): 0.2	0.245
Total	11	3.98			

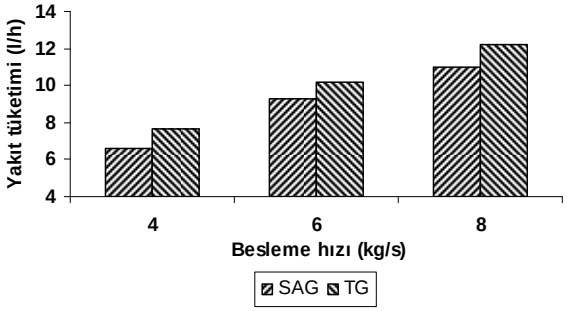

Figure 4. The changing of fuel consumption depending on feed rate of machine

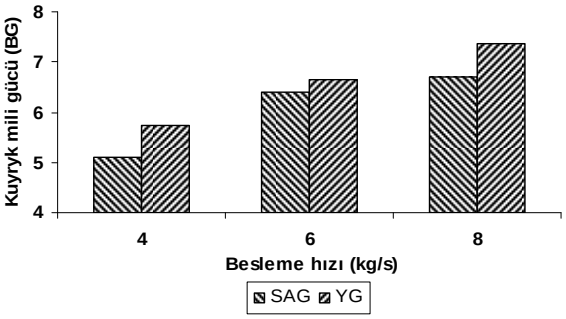

Figure 5. The change of power take of connected with feed rate of machine

It is found that the power take of changes between 5.09 – 7.36 HP (Figure 5). The power take of is 6.59 HP in the fresh manure with high bulk density and shearing stress. But it is 6.06 HP in separated manure with 8% decrease. The values of fuel consumption increase depending on increasing feed rate. 100% increase in feed rate increases power take of 34%. The values of power take of in the study are obtained smaller than the values of machine. With horizontal or vertical drum spreader which is given in literature. It can be said that spreader type and holding system geometry cause this situation. The effect of manure type and feed rate on fuel consumption is significant ($P<0.01$) (Table 6).

As a result the evaluation below can be said:

• Because of irregular manure distribution symmetry, distribution uniformity is better on the condition that turning working.

• Effective working width of machine with disc which is used in the study is found fairly higher than horizontal or vertical spreader with drum which is given in the literature.

• On the condition that turning working, both effective working width and changing limits of working width are found fairly high in all the combinations which is taken to test.

• Type of manure, feed rate of machine and the effect of wing position on distribution uniformity are found significant.

• Distribution uniformity of machine, fuel consumption and the values of requirement of power take of increase connected with increasing feed rate.

Table 6. The results of variance analyses and LSD test which is done on the values of power take of

V.S.	D.F.	M.S.	F	Manue	Feed rate
Manure (G)	1	0.84	6.09**	G_1 6.59 $_a$	q_1 5.41 $_a$
Feed rate (q)	2	5.78	41.71**	G_2 6.06 $_b$	q_2 6.53 $_b$
G*q	2	0.08	0.63ns		q_3 7.25 $_c$
Error	6	0.13		LSD(%5): 0.52	0.645
Total	11	1.22			

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