Kasetsart J. (Nat. Sci.) 45 : 824 - 831 (2011)

Evaluation of Vetiver Grass Buffer Strips and Organomineral Fertilization for the Improvement of Soil Physical Properties

Effiom Oku[1, 2]*, Olajire Fagbola[3] and Paul Truong[4]

ABSTRACT

Soil erosion still remains the major cause of deterioration of soil physical qualities on cultivated lands worldwide. A study was carried out on erosion plots at the Teaching and Research Farm of the University of Ibadan, Nigeria to assess soil physical properties after five years of using vetiver grass buffer strips (VGBS) and organomineral fertilizer (OMF) with bare soil on which farmers had planted without soil conservation measures as the control. Samples were analyzed for water stable aggregates (WSA), mean weight diameter (MWD), bulk density, porosity and particle size distribution. The cone index (CI) was also assessed. Infiltration values were fitted to Philip's and Kostiakov's models. Results showed that the amount of WSA for the VGBS and OMF plots was the same (64%) and on the bare soil was 54%. The MWD on the VGBS plot was 6.11% higher than on the OMF plot and 19% higher than on bare soil. The bulk density for the bare soil was 4% higher than that of the VGBS plot. Porosity values for the VGBS and OMF plots were the same, being 8% higher than the bare soil plot. The CI was 15.7% and 7% lower on the VGBS and OMF plots, respectively, compared to the bare soil. Cumulative and initial one-minute infiltration increased by 39.4% and 35%, respectively, on the VGBS plot when compared with the bare soil. Hydraulic conductivity increased by 41.7% on the VGBS plot when compared with bare soil. The initial capacity of the soil to accept water increased on the VGBS plot by 19% over the OMF plot and 39% over the bare soil plot. The index of soil sorptivity (reflecting rate of decline of infiltration capacity) was the same for the VGBS and OMF plots and 21.78% higher than for the bare soil plot. The use of vetiver grass buffer strips on erosion-prone cultivated fields over the years could act as a source of organic fertilizer, improving soil physical properties.

Keywords: soil conservation, soil structure, soil degradation, soil erosion, Nigeria

INTRODUCTION

Humans depend to a large extent on the soil. In addition, soils are the natural substrate in which plants grow and are central to food security and world peace. Considering the importance of soil to humans, there is need for it to be conserved to prevent it from being eroded by either water or wind. The soil of south western Nigeria is eroded mainly through water as high intensity rainfall removes the top soil (Babalola *et al.*, 2003) and soil erosion leads to a decline in the soil structure and low soil productivity.

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[1] Permanent and postal address: Department of Soil Science, Faculty of Agriculture, University of Abuja, 900001, Nigeria.

[2] Abdus Salam International Centre for Theoretical Physics, Trieste, Italy.

[3] Department of Agronomy, University of Ibadan, Nigeria.

[4] Vieticon Consulting, Brisbane, Queensland, Australia.

* Corresponding author, e-mail: effiomessienoku@yahoo.co.uk

Received date : 13/01/11 Accepted date : 23/05/11

Soil erosion is a major constraint to food production in Nigeria and other developing countries as most small-holder farmers cultivate lands whose slopes range from gentle to very steep. This increases the stress on sloping lands which are considered not suitable for cultivation because it is difficult to retain soil and plant nutrients on sloping lands and achieve adequate crop growth and performance. Hellin (2003) observed that the cultivation of steep lands is a common practice throughout the tropics. Hence, it is common to hear farmers report that their soil is getting ‘thinner’, stony and ‘tired’ (LEISA, 2003). In the face of deepening poverty, the uneven distribution of scarce arable land and population pressure, the cultivation of steep land will continue in the foreseeable future (Juo and Thurow, 1998).

Severe soil erosion still continues and will continue to persist on agricultural lands and will pose a formidable threat to environmental quality in Nigeria and other developing countries. The consequence of accelerated soil erosion is increased land degradation, loss of soil structure and soil compaction. Hence, efforts should be geared towards maintaining the productivity of steep agricultural lands for the survival of the rural peasants and their families.

Population pressure and land degradation are major problems that work in tandem. Much of the lands within the tropical belt are biophysically incapable of supporting some type of sustainable agriculture. Much of their sustainability is dependent on the extent of inputs to maintain the physical quality of the soil. According to Babalola (1988), the detachment of soil particles from the land mass and the transportation of the loosened materials to another place, leaving behind barren soils, is perhaps the most fearsome threat confronting humans today. Curbing this threat requires soil conservation measures that are cheap, replicable and sustainable. This threat to sustainable environmental and agricultural productivity has led to considerable interest in soil conservation technologies that control runoff and erosion. Cross slope technologies such as bunds and barriers do little to improve the quality of the soils between the barriers. As a result, farmers seldom witness an improvement in soil physical properties and agricultural production as a result of such soil conservation methods. A proven solution to soil erosion has been found with vetiver grass buffer strips (VGBS).

Vetiver grass (*Vetivera* spp.) is a tropical plant from India that is well adapted to different environmental conditions. It is the dominant grass species in Thailand and it is found in a wide range of areas from the highlands to lowlands but is found only scantily in the wild in Nigeria. It appears in dense clumps and is fast growing through tillering. The clump diameter is about 30 cm with a height of 50 to 150 cm. The narrow, erect and rather stiff leaf is about 75 cm long and 8 mm wide. The horizontal expansion of the root system being limited to only 50 cm imposes no obstacle to nearby plants and in particular is considered an effective measure for soil and water conservation (World Bank, 1993). To control soil loss by erosion and improve soil physical properties, the use of vetiver grass was considered to be a major breakthrough in soil conservation (World Bank, 1990). When planted across the contour on slopes, it holds back eroded soil, while the clump stands above the ground and produces tillers forming a green hedge. Hence, this makes it capable of trapping eroded sediment, residues and runoff associated with heavy tropical rains, dispersing runoff and leading to the formation of natural earth terraces that eliminate the erosive power of the runoff. Studies in Nigeria and elsewhere have shown a reduction in runoff, soil loss and increased crop yield with the use of VGBS (Troung and Baker, 1998; Babalola *et al*., 2003; Oku, 2004; Troung and Loech, 2004).

Organic matter when incorporated into the soil is capable of improving soil physical properties and providing enhanced infiltration. In

Nigeria, a research group at the University of Ibadan developed an organomineral fertilizer (OMF), in which animal wastes and plant residues from farms and cities were composted to reduce the volume, converted into pellets for easy handling and fortified with inorganic nitrogen (Omueti *et al*., 2000). The OMF is a low input technology for improving the poor physical fertility status of tropical soils to achieve sustainable crop production and land use (Adeoye *et al*. 2008; Ojeniyi *et al*., 2009). According to Babalola *et al*. (2003), any practice that improves soil physical properties will enhance water entry into the soil. Therefore, the present study was carried out using erosion-prone soil to determine the effects of VGBS intervention and OMF application on the physical properties of the soil.

MATERIALS AND METHODS

The study was carried out in 2008 on experimental erosion plots located on a 6% slope at the Teaching and Research Farm, University of Ibadan, Nigeria (latitude 7°7′ N and longitude 3°5′ to 3°36′ E). Ibadan is located 228 m above sea level and has a mean annual rainfall of 1289.2 mm based on 27 y of records (Alabi and Ibiyemi, 2000). The natural vegetation is transformed into derived savannah. The soil is Alfisol underlain by the basement complex rock. The erosion plots were constructed in 2003 and all treatments plots continuously planted each year to maize. The three treatments were VGBS, OMF and bare soil. Each VGBS was planted across the erosion plot at 10 m spacing down the slope. OMF was broadcast and manually worked into the soil with a hand hoe during the construction of ridges. The control consisted of the traditional farming practice of bare soil along the cultivated slope without any erosion control. The treatments were set up in a randomized complete block design with three blocks. Each erosion plot had a length of 40 m and 3 m width. The VGBS was 3 m wide. Planting was carried out on ridges 1 m apart in all treatment plots. Cultivation was undertaken between the VGBS barriers.

A rigid grid sampling method was used. Undisturbed core samples were collected at at 5 m intervals down the slope at a depth of 0–30 cm using a cylindrical core of 30 cm length and 6.5 cm inner diameter. The samples were bulked to get composite samples. Core samples were analysed for dry bulk density, porosity and macro aggregate stability analysis based on water stable aggregates (WSA) and mean weight diameter (MWD). Particle size analysis was carried out using a hydrometer method (Gee and Bauder, 1986). Bulk density was determined by the core method (Burke *et al*., 1986). Porosity was calculated as a function of the total volume not occupied by soil solids assuming a particle density of 2.65 Mg m^{-3} (Danielson and Sutherland, 1986). The amount of water stable aggregates at 0–30 cm soil depth was determined with air-dried samples. The aggregates were wet sieved according to the Yoder (1936) modified technique (Whitbread *et al*., 1996; Oku, 2004) using a graduated nest of sieves of sizes 4.7 mm, 2 mm, 1 mm and 0.25 mm. The process involved spreading a 50 g soil sample on the topmost of the nest of four sieves, immersing the sieves in water while raising and lowering the nest of sieves through water 20 times. The stable aggregates on each sieve were washed into separate moisture cans. The contents of each aggregate were oven dried at 105 °C to a constant weight. Correction for sand used sodium hydroxide (NaoH) as a dispersing agent. The percentage WSA was calculated using Equation 1 as reported by Kemper and Rosenau (1986):

$$\% \text{ WSA} = \frac{\text{weight of soil retained on sieve } - \text{ weight of sand}}{\text{total sample weight d weight of sand}} \times \frac{100}{1} \quad (1)$$

A preliminary test was conducted using 10, 20 and 30 cycles of lowering and raising in a pool of water 50 cm deep. The breakdown of aggregates after 10, 20 and 30 cycles of lowering and raising in a pool of water for each soil was determined. The MWD of the WSA of the soil under the different treatments was calculated. Twenty cycles of lowering and raising in a pool of water gave the highest value for MWD and so 20 cycles was chosen. The MWD or size distributions of the WSA were determined using the method of Anger and Mehuys (1993). A cone penetrometer was used according to Bradford (1986) to measure the soil mechanical resistance and the values were read from the cone index (CI). Water infiltration over 100 min was determined with a double ring infiltrometer having a 30 cm inner diameter and 60 cm outer diameter (Michael, 1978). One-minute and cumulative infiltration rates were evaluated and were further fitted to the infiltration models of Philip (1957) and Kostiakov (1932) to evaluate the hydrological behavior of the soil (sorptivity, transmissivity and index of soil sorptivity, reflecting the decline of infiltration rate).

$$I = {}^{1}/_{2}\, St + At \qquad \text{(Philip's model)} \qquad (2)$$

$$I = Ct^{\alpha} \qquad \text{(Kostiakov's model)} \qquad (3)$$

where;
I = cumulative infiltration (cm)
t = time (min or h)
C/S = initial infiltration (cm min^{-1} or cm h^{-1})
A = transmissivity (hydraulic conductivity)
α = index of soil sorptivity reflecting the decline of infiltration rate

The coefficient of variability (CV %) of infiltration and its characteristics were calculated. The CV values were grouped into least (low) variable, CV < 15%; moderately (medium) variable with CV = 15 to 35%, and highly (high) variable with CV > 35% (Upchurch *et al.*, 1988; Wilding *et al.,* 1994). Significance was tested at the 0.05 level.

RESULTS AND DISCUSSION

Organomineral fertilizer (OMF) composition

The nutrient composition of the OMF applied to the erosion plots for this study is presented in Table 1. The OMF had considerable amounts of N, P, K and Ca on incorporation into the soil and subsequent decomposition of the material would release these chemicals for enhancement of soil aggregate stability through the binding of the soil separates.

Soil structural properties and particle size distribution

Table 2 shows the soil structural quality after 5 y of the treatments (VGBS, OMF and bare plots). WSA values between the VGBS, OMF and bare soil were significantly different but the WSA values for the VGBS and OMF plots were not significantly different. The WSA value on bare soil was significantly the lowest. The macro aggregate stability index values measured by MWD for VGBS, OMF and bare soil were 1.6, 1.5 and 1.3 mm, respectively, (Table 2). The VGBS was better than the other treatments, with the OMF application treatment the next best whereas the bare soil had the least value for MWD indicating that bare soil had less stable aggregates. The MWD values on the vetiver intervention plots were 6.1% higher than for the OMF plots and 19% higher than on bare soil. The WSA value on bare soil was 12.5%, which was significantly lower than on the vetiver and OMF treatment plots. Total porosity

Table 1 Analysis of organomineral fertilizer used in the study.

Element	OMF nutrient content (%)
N	0.94
P	0.28
K	1.15
Ca	1.19
Na	nd

OMF = organomineral fertilizer; nd = not determined values were inferred from bulk density values. Porosity values for the vetiver and OMF plots were equally high (51%) and lowest (47%) for the bare soil. The porosity was 8.5% significantly higher for the VGBS and OMF-treated plots than for the bare soil. The porosity value of 47% for the bare soil plots is rated by Kachinskii (1970) as ‘good’ for agricultural practice whereas porosity values above 50% (as was recorded for the VGBS and OMF plots) are rated as ‘best’ for agricultural practice in tropical soils. The low porosity value implies that aeration, root penetration and plant development will be restricted on bare soil (Oku and Edicha, 2009). This indicates that vetiver and the OMF, being an organically based fertilizer, will improve the porosity of the soil. The cone index (CI) for the VGBS intervention plots was 15.7 and 7% lower than the bare soil and OMF-treated plots, respectively. The physical qualities in the vetiver intervention plots were comparatively better.

The particle size distributions under the studied treatments are presented in Table 3. Bare soil had the highest sand fraction with the lowest clay fraction when compared to the VGBS intervention and OMF application plots. In the absence of an erosion barrier (the vetiver grass buffer strips) or a soil particle-binding agent like the OMF, water erosion makes sandy soils even sandier as a result of runoff moving the finest particles away, leaving coarse particles behind (Oku, 2004).

Infiltration rates

The initial one-minute and cumulative infiltration under VGBS, OMF and bare soil are shown in Table 4. Initial one-minute infiltration when compared with the OMF plots showed a significant decline by 12.5% for the vetiver and 43.75% on bare soil. There was a 12.8% decrease in cumulative infiltration under the influence of VGBS after 100 min and a 47.2% decline in cumulative infiltration on bare soil. This shows the advantage of an organic source fertilizer in improving water infiltration. Cumulative infiltration under VGBS increased significantly by 39.4% and initial one-minute infiltration increased by 35% when compared with bare soil. Infiltration is the key to soil and water conservation (Babalola, 1988); thus, this comparative increase in infiltration on the VGBS plots over the bare soil plots indicates that VGBS is effective in soil and water conservation.

Table 2 Soil structural quality of vetiver, organomineral fertilization and bare soil plots.

Treatment	WSA(%)	MWD(mm)	BD(g cm^{-3})	P(%)	CI(Kpa)
Vetiver	64	1.6	1.3	51	330.1
OMF	64	1.5	1.3	51	364.3
Bare soil	56	1.3	1.4	47	391.8
P = 0.05	3.2	0.1	ns	ns	23.4

WSA = water stable aggregate; MWD = mean weight diameter; BD = bulk density; P = porosity; CI = Cone Index; Vetiver = vetiver grass buffer strip; OMF = organomineral fertilizer application; Bare soil = traditional farming practice; ns = not significant.

Table 3 Particle size distribution (g kg^{-1}) of vetiver, organomineral fertilization and bare soil plots as induced by water erosion.

Treatment	Gravel	Coarse sand	Fine sand	Silt	Clay
Vetiver	229.1	458.5	289.9	137.5	113.8
OMF	208.3	494.2	279.3	109.3	117.3
Bare soil	230.4	460.8	302.0	126.8	110.5

Table 4 One-minute and cumulative infiltration on plots under vetiver, organomineral fertilization and bare soil.

Treatment	One-minute infiltration ($cm\ min^{-1}$)	Cumulative infiltration (cm per 100 min)
Vetiver	2.8	90.7
OMF	3.2	104.0
Bare soil	1.8	54.9
P = 0.05	0.8	17.6
CV %	28	31

CV = coefficient of variability.

The infiltration characteristics on the erosion plots under VGBS, OMF and bare soil treatments are shown in Table 5. Values of infiltration parameters obtained from the Philip's and Kostiakov's models were low. Transmissivity increased by 41.7% under the influence of VGBS when compared with bare soil but decreased by 23% when compared with the OMF-treated plots. The initial capacity of the soil to accept water under the Philip's model increased by 19% over OMF and 39% over the bare soil. The index of soil sorptivity, reflecting the decline in the infiltration rate of Kostiakov's model, was the same for the vetiver and OMF-treated plots and represented a 20.8% increase over the bare soil. The A and S values were moderately variable (CV = 15–35%) among the vetiver, organomineral fertilizer (OMF) and bare soil plots. The C and α values were the least variable (CV < 15%). The initial one-minute infiltration and cumulative infiltration were moderately variable among the treatments.

CONCLUSION

Organomineral fertilizer, being of organic origin, improved the soil physical properties. The VGBS on the cultivated slope evaluated after five years had positively influenced the soil physical properties, especially the structural quality. The current study demonstrated that VGBS was effective in enhancing the soil physical properties. Vetiver used at strip intervals of 10 m enhanced water infiltration in the study. Porosity values for the vetiver intervention plot and the bare soil were rated "best" and "good", respectively, for agricultural practice. The CI values were lower for the vetiver than the bare soil and OMF-treated plots. The WSA and MWD

Table 5 Soil hydrological behavior under vetiver, organomineral fertilizer and bare soil using Philip's and Kostiakov's infiltration models.

Treatment	Philip's model			Kostiakov's model		
	A	S	R^2	C	α	R^2
Vetiver	0.6	3.52	0.9	0.45	0.77	0.97
OMF	0.78	2.86	0.99	0.46	0.99	0.99
Bare soil	0.35	2.14	0.9	0.46	0.61	0.9
P = 0.05	0.2	0.6		ns	0.1	
CV %	31	20		1	13	

A = tranmissivity; S = sorptivity; C = index of initial infiltration; a = index of soil sorptivity, reflecting the decline of infiltration rate; R^2 = correlation coefficient; CV = coefficient of variability; ns = not significant.

were equally ameliorated and the values comparatively higher than those of bare soil. The results showed that if vetiver is established in the field for some years, then it will behave as organic matter and become incorporated into the soil to rebuild the soil structure.

LITERATURE CITED

Adeoye, G.O., O.O. Adeoluwa, M. Oyekunle, M.K.C. Shrinder, E.A. Makinde and A.A. Olowoake 2008. Comparative evaluation of organo-mineral fertilizer and mineral fertilizer (NPK) on yield and quality of maize. **Nigerian J. of Soil Sci.** 18: 132–137.

Alabi, R.T. and A.G. Ibiyemi. 2000. Rainfall in Nigeria and food crop production, pp 63–66. *In* M.O. Akoroda, (ed.). **Agronomy in Nigeria.** University of Ibadan, Nigeria.

Anger, S.D. and G.R. Mehuys 1993. Aggregate stability to water, pp 651–657. *In* M.R. Carter, (ed.). **Soil Sampling and Methods of Analysis.** Canadian Society of Soil Science. Lewis Publishers. Florida.

Babalola, O. 1988. Soil properties affecting infiltration, runoff and erodibility, pp 131–145. *In* S.O. Sagua, E.E. Enabor, G.E.K. Ofomata, K.O. Ologe and O. Oyegbande, (eds.). **Ecological Disaster in Nigeria.** Federal Ministry of Science and Technology, Lagos, Nigeria.

Babalola, O., S.C. Jimba., O. Maduakolam and O.A. Dada 2003. Use of vetiver grass for soil and water conservation in Nigeria. pp 293–300. *In* P. Truong and H. Xing, (eds) **Proceedings of the Third International Conference on Vetiver and Exhibition. Vetiver and Water.** Guangzhous, China, October, 2003. China Agriculture Press.

Bradford, J.M. 1986. Penetrability, pp 463–478. *In* A. Klute, (ed.). **Method of Soil Analysis Physical and Mineralogical Methods.** Agronomy Society of America/Soil Science Society of America, Madison, Wisconsin.

Burke, W., D. Gabriels and J. Bouma. 1986. **Soil Structure Assessment.** Balkema, A. Rotterdam. Boston.

DanielsonR.E. and P.L. Sutherland 1986. Porosity, pp 443–461. *In* A. Klute, (ed.). **Methods of Soil Analysis Physical and Mineralogical Methods.** Agronomy Society of America/Soil Science Society of America, Madison, Wisconsin.

Gee, G.N. and J.W. Bauder 1986. Particle size distribution, pp 383–411 *In* A. Klute, (ed.). **Methods of Soil Analysis Physical and Mineralogical Methods**. Agronomy Society of America/Soil Science Society of America. Madison, Wisconsin.

Hellin, J. 2003. From soil erosion to soil quality. **Magazine on Low External Input and Sustainable Agriculture** 19(4): 10–11.

Juo, A.S.R. and T.L.Thurow. 1998. **Sustainable Technologies for Use of Conservation of Steep Lands.** Texas A & M University and Texas Agricultural Experimental Station College Bulletin.

Kachinskii, N.A. 1970. Soil Physics. P. 11 Mir Publishers. Quoted in S.V. Zonn, 1998. **Tropical and Subtropical Soil Science.** Moscow, Mir Publishers. 497pp.

Kemper, W.D. and R.C. Rosenau. 1986. Aggregate stability and size distribution, pp 425–442 *In* A. Klute, (ed.). **Methods of Soil Analysis Physical and Mineralogical Methods.** Agronomy Society of America/Soil Science Society of America. Madison, Wisconsin.

Kostiakov, A.N. 1932. On the dynamics of the coefficient of water percolation in soils and on the necessity of studying it from dynamic point of view for purposes of amelioration. *In* **Trans 6th Commission.** Soil Science Society of Moscow part A. 17–21.

LEISA. 2003. Reversing degradation. **Magazine on Low External Input and Sustainable Agriculture** 19(4): 3–4.

Michael, A.M. 1978. **Irrigation: Theory and Practice.** Vikas Publishing House. PVT Ltd. New Delhi. 379pp.

Oku, E.E. 2004. **Changes in Soil Physical Properties Down the Slope as Induced by Water Erosion.** M.Sc. project. Department of Agronomy, University of Ibadan, Nigeria. 133pp.

Oku, E.E. and J. Edicha 2009.The physical properties of some soil profiles and management of an erosion prone soil in southwestern Nigeria. **J. of Agric. Forestry and the Soc. Sci. (JOAFSS)** 7(1): 180–109.

Omueti, J.A.I., M.K.C. Sridhar, G.O. Adeoye, O. Bamiro and D.A. Fadare. 2000. Organic fertilizer use in Nigeria our experience, pp 208–215. *In* M.O. Akoroda, (ed.). **Agronomy in Nigeria.** University of Ibadan, Nigeria.

Ojeniyi, S.O., O. Owolobi, O.M. Akinola and S.A. Odedina. 2009. Field study of effect of organo-mineral fertilizer (OMF) on maize growth, soil and plant nutrient composition in Ilesha Southwest Nigeria. **Nigerian J. of Soil Sci.** 19: 11–16.

Philip, J.R. 1957. The theory of infiltration: Captivity and algebraic infiltration equations. **Soil Sci.** 84: 257–264

Truong, P.N. and B. Baker. 1998. Vetiver grass system for environmental protection. *In* **Technical Bulletin No. 1998/1. Pacific Rim Vetiver Network. Office for the Royal Development Projects Board.** Bangkok, Thailand.

Truong, P.N. and R. Loech. 2004. Vetiver systems for erosion and sediment control. *In* **11th International Soil Conservation Organization Conference.** Brisbane. July 4–7.

Upchurch, D.R., L.P. Wilding and J.L. Halfield. 1988. Methods to evaluate spatial variability, pp 201–229. *In* L.P. Wilding and J.L. Halfield, (eds.). **Reclamation of Disturbed Lands.** CRC Press. Boca Raton, Florida, USA.

Wilding, L.P., J. Bonma and D.W. Boss. 1994. Impact of spatial variability of interpretive modelling, pp 61–75. *In* R.B. Bryant and R.W. Arnold, (eds.). **Quantitative Modelling of Soil Forming Processes.** Soil Science Society of America Special Publication No 39.

Whitbread, A.M., R.D.B. Lefroy and G.J. Blair 1996. Change in soil physical properties and soil organic carbon contents with cropping on a red brown earth soil. *In* **8th Australian Agronomy Conference.** Toowoomba, Queensland.

World Bank. 1990. **The World Bank News.** Vol xii. Nos 4.

__________. 1993. **Vetiver Grass a Thin Green Line Against Erosion.** National Academy Press, Washington DC. 213pp.

Yoder, R.E. 1936. A direct method of aggregate analysis and a study of the physical nature of erosion losses. **Agronomy J.** 28: 3337–3351.