INTRODUCTION

Human population increased to slightly over 7.3 billion people at the end of 2016 (U.S. Census Bureau, 2017) and is projected to reach 9.7 billion by 2050 (UN, 2015). Total food production has been able to keep pace (Egli, 1998; Alexandratos and Bruinsma, 2012) with population growth until nowadays,but a dramatic increase in food production will have to take place by 2050 (Wik et al., 2008; Tilman et al., 2011) in order to sustain this larger population (FAO, 2009). Recent estimations forecast that these increases could be in the range from 70% (Bruinsma, 2009; FAO, 2009) to 100-110% (Tilman et al., 2011).

In order to achieve this paramount goal, four basic strategies could be explored (Evans, 1993; Wik et al., 2008; Tilman et al., 2011), as follows: a) expansion of the physical area under cultivation; b) increase of the crop yield per unit area; c) increase in the cropping intensities (i.e., more crops per unit area per year and/or shorter fallow periods); d) replacement of lower yielding with higher yielding crops. Achieving future production goals will not be easier than in the past, as additional land and water resources to explore are becoming scarcer (Alexandratos and Bruinsma, 2012). The Ecological Intensification system, described as “a system that satisfies the anticipated increase in food demand while meeting acceptable standards of environmental quality” (Cassman, 1999), focuses on greater yields from existing agricultural land with minimal environmental impacts (Royal Society, 2009).

Plant density greatly influences the crops ability to capture radiation, water and nutrients (Puckridge and Donald, 1967; Satorre, 1999). Improved grain yield per unit area of modern hybrids is due to increased tolerance to greater plant populations rather than improved yield per plant (Nafziger, 1994; Tokatlidis and Koutroubas, 2004). In general, intercepted radiation and corn productivity (both biomass and grain) show a parabolic response to increased plant density (Kruk and Satorre, 2003), up to the point where further plant density increases do not translate into greater plant productivity (Tollenaar and Bruulsema, 1988; Major et al., 1991; Westgate et al., 1997) or solar interception values (Tetio-Kagho and Gardner, 1988; Tollenaar and Bruulsema, 1988).

Future increases in corn yields will depend on sophisticated management of soil resources and inputs (Cassman, 1999; Mueller et al., 2012; Ruffo et al., 2015). Splitting N applications among different corn growth stages can to reduce N losses and increase overall use efficiency (Torbert et al., 2001; Scharf et al., 2002; Grant et al., 2012). Applications of foliar fertilizer during corn flowering and the grain filling period increased grain yield by around 6% in one year, but not in the other, in Iowa experiments (Harder et al., 1982), and 8% in one-location year out of six in Quebec (Tomar et al., 1988).

Similar to N, concerns about the efficiency in the use of P, have been recently on the rise (Sharpley et al., 1994; Bennet et al., 2001). Greater crop yields result in greater P removal and while most US states depend on well-validated land grant university-developed soil test recommendations, most of those data were developed more than 20 years ago (Heckman et al., 2003; Laboski et al., 2006). The amount and timing of P uptake and partitioning by modern hybrids may also differ from that of older hybrids, resulting in P fertilizer response at soil test levels that were previously thought to be adequate (Bender et al., 2013)

The intensification of cropping systems has increased the need for a reappraisal of the K-fertilization practices for corn on Ultisol soils in Southeastern US (Heckman and Kamprath, 1992). Total K uptake and timing are also different between modern and older corn hybrids (Heckman and Kamprath, 1992; Bender et al., 2013). Grain yield responses to potassium (K) application, have been inconsistent in the US, with several studies showing grain yield increases (Mallarino et al., 1999; Ebelhar and Varsa, 2000), minimal to no changes (Bruns and Ebelhar, 2006) and yield decreases (Wortmann et al., 2009) with K fertilization depending on soil fertility status and mineralogy.

Application of quinone-outside inhibitors (QoI) in corn, more commonly known as strobirulin-based fungicides, has been extensively promoted over the last 10 years in the US, although there is limited evidence showing a consistent increase in corn yields and economic profitability derived from its use (Paul et al., 2011). Besides its action on plant disease control, authors have claimed that QoI products may increase both the duration of a green canopy and the photosynthesis rates, water and nitrogen use efficiencies, while also decreasing leaf respiration rates (Glaab and Kaiser, 1999; Nason et al., 2007). In a thorough meta-analysis of 212 studies from 14 states in the US conducted in the period 2002 through 2009, Paul et al. (2011) found small positive yield differences between treated and untreated plots in the range of 0.23 to 0.39 Mg ha^{-1} resulting from applying different QoI fungicides.

A number of crop management practices and inputs are reported to increase corn grain yields, but most research to date has focused on a refined evaluation of a single practice or input and not on the combined effects of these practices.The objectives of this study were to: a) evaluate and document the individual and combined effect of different management practices for corn grown in the mid-Atlantic USA; and b) calculate the economic break-even analysis for each combination of practices and levels.

MATERIALS AND METHODS

A total of five trials were conducted in the Coastal Plain region of Virginia from 2012-2014. Treatments consisted of the “Standard” farmer practice which represents broadly the recommended corn management practices currently implemented by farmers in the region; the suite of practices identified for inclusion in the “Ecological Intensification” (EI) treatment that were hypothesized to potentially increase yield over current management; and single factors either added to the Standard or removed from the EI for each additional treatment.

Field trials were conducted in 2012, 2013 and 2014 near Lanexa in New Kent county, in 2013 at Virginia Beach and 2014 in Northumberland county, Virginia, all located in the mid-Atlantic physiographic province known as Coastal Plain. Generally speaking, soils in this region are infertile, acid, highly weathered and vary from sandy to very clayey textures.

Experimental design approach

In order to assess the individual and combined impacts of potentially beneficial management practices in grain yields, six treatment factors were studied: a) seeding rate; b) in-season nitrogen rate and application time; c) additional phosphate fertilizer, SS kg ha^{-1} over soil test recommendation, applied preplant; d) additional potassium fertilizer, SS kg ha-1 over soil test recommendation, applied preplant; e) foliar triazole N application at R1 growth stage; and f) foliar application of a strobirulin fungicide, also at R1. Treatments were arranged in a split plot design with an incomplete factorial arrangement of treatments. Seeding rate was treated as the main plot and production system (i.e., the remaining five factors) as the subplot. Four replications were established at each location-year site resulting in a total of 56 experimental units (EUs) at each site. Plots were 3.1-m wide (i.e. 4 corn rows) by 9.1-m long.

Prior to planting, composite soils samples to a depth of 15 cm were taken from each experimental area and analyzed for routine soil chemical composition. Fertilizer application amounts and dates are listing in Table 1. All sites were grown under rainfed conditions.

Hybrids DEKALB ‘DKC 65-19’ (115 CRM), Pioneer Brand ‘P1319HR’ (113 CRM) and Pioneer Brand ‘P0604AM’ (106 CRM) were no-till seeded in 0.76-m rows following soybean between April 15 and April 28, at the New Kent (3 growth seasons), Virginia Beach and Northumberland sites, respectively (Table 1).

Each one of the factors included in the experiment consisted of two levels, one representing the standard level for the factor currently used by local farmer at each site, and the second representing "intensification" in the level of the factor. The practice using all factors at their standard level defines the "Farmer standard" (FS) treatment, while the inclusion of all experimental factors at their intensified levels defines the "Ecological intensification" (EI) treatment. Addition of factors at their intensified level, added to what would otherwise be the FS treatment, while keeping other factors at their standard level (also referred as "FS plus single factors") results in six treatments to be compared with the "full" FS treatment. Similarly, replacement of an intensified factor by its standard level in the EI treatment (also referred as "EI minus single factors") results in six treatments to be compared with the "full" EI treatment. Consequently, a total of fourteen treatments were studied in this experiment (Table 2).

Seeding rate at the standard level was 67,000 seeds ha^{-1} at New Kent (2012 through 2014), and 89,000 seeds ha^{-1} at Virginia Beach 2013 and Northumberland 2014. In order to create the intensified level of the factor, seeding rates were increased by 15-18%, resulting in rates of 79,000 seeds ha^{-1} at New Kent (2012 through 2014) and 101,000 seeds ha^{-1} at Virginia Beach 2013 and Northumberland 2014. The standard level for nitrogen fertility management was a single 112 kg N ha^{-1} sidedress application at V4 (Abendroth et al., 2011) as UAN (30-0-0). The intensified level of this factor consisted of the application of 135 kg N ha^{-1} split into three applications of 45 kg N ha^{-1} each at V4, V6 and V10. For the third and fourth factor, phosphate and potassium management, respectively, the standard level of each factor received only the P and K recommended by Virginia Cooperative Extension soil test recommendations. At their intensified levels, extra doses of 56 kg P_2O_5 ha^{-1} supplied in the form of MicroEssentials SZ [MES SZ; 12-40-0-10(S)-1(Zn)] (The Mosaic Company, Plymouth, MN) and 84 kg K_2O ha^{-1} as potassium chloride (KCl; 0-0-60) were broadcast at planting. The standard and intensified levels of the fifth factor were either the absence or the application of a foliar triazole nitrogen product (CoRon, 25-0-0-0.5Fe) (Helena Chemical Company, Collierville, TN) at anthesis (VT), respectively. The last factor studied in our comparisons, included either none or the application of a strobilurin-based fungicide (Headline, Pyraclostrobin 23.6%) (Basf SE, Ludwigshafen, Germany) at its standard and intensified level, respectively. In the latter case, fungicide was applied to the upper leaves in the crop canopy, also at VT, with a handheld CO2 sprayer at a rate of 0.94 l ha^{-1} in 100 liters ha-1 of water held above the crop.

After reaching maturity, corn was hand harvested from a 4.65 m^2 area from each experimental unit from the center two rows. Ears fresh weight was recorded for all the ears harvested in each plot. Following, a subsample of six ears was randomly chosen and placed into a 60°C forced air oven until constant mass to determine moisture. Finally, kernels were shelled from the cobs and weighed to get total sample kernel weight and used to calculate final grain yields, expressed as Mg dry matter grain (15.5% % moisture) ha^{-1}.

Weather data was obtained from the National Oceanic and Atmospheric Administration (https://www.ncdc.noaa.gov/). Daily weather data (total precipitations in mm; daily average temperature and daily maximum temperature, both in °C) were collected for the period April through September in 2012, 2013 and 2014 at New Kent, 2013 at Virginia Beach, and 2014 at Northumberland (data not shown).

For statistical analysis, LSMeans were separated using two means t-test marginal pairwise comparison with proper control treatments (i.e., EI and FS) in SAS 9.3 (2002-2010 by SAS Institute Inc., Cary, NC, USA) with significances set at $p \leq 0.10$.

RESULTS(see table 3 for a summary of effects)

- ✓ In 8 out of 60 pairwise comparisons across sites differences in corn grain yields were found either when adding (6 cases) or removing (2 cases) single factors to the "farmer standard" (FS) or "ecological intensification" (EI) management packages, respectively.
- ✓ When significant differences occurred,

  a) Increasing seeding rate from 67,000 to 79,000 seeds/ha produced mixed results in New Kent location, with yield increases in NK-12 (+605 ha^{-1}) and decreases in NK-13 (-2,521 kg ha^{-1}). Increasing rates from 89,000 to 101,000 seeds/ha resulted in yield increases in VB-13 (+2,487 kg ha^{-1}).

  b) Adding 84 kg K ha^{-1} in NK-13 reduced yields by 3,533 ha^{-1}.

  c) Splitting N fertilization increased yields by +1,112 kg ha^{-1} in VB-13. When N split management was removed from the EI package, yields dropped drastically in NK-13 (-6,468 kg ha^{-1}) and across sites-years (-2,199 kg ha^{-1}).

  d) Adding foliar N application at VT increased yields in VB-13 (+1,368 kg ha^{-1}). In NK-12, removing foliar N from EI package resulted in marginal yields increases (+363 kg ha^{-1}).
- ✓ Over sites, grain yields for full EI treatment were significantly greater (+1,700 kg ha^{-1}) than those for full FS.
- ✓ It was economically viable (not including additional cost for management) to use those practices. Spent $167 more per ha with the EI system, but generated $254 more. Overall return to variable costs is approximately $ 86.7 per ha for the higher yielding system (see Figure 2).
- ✓ Higher yields required a 'systems' approach of intensifying inputs/management in many areas to achieve optimum results.

Literature cited

-Alexandratos, N., and J. Bruinsma. 2012. World Agriculture towards 2030/2050: The 2012 Revision. ESA Working Paper No. 12-03. Agricultural Development Economics Division (ESA). FAO, Rome, Italy, 147 p.
-Bartlett, D.W., J.M. Clough, J.R. Godwin, A.A. Hall, M. Hamer, and B. Parr-Dobrzanski. 2002. The strobirulin fungicides. Pest. Manag. Sci. 58: 649-662.
-Bender, R.R., J.W. Haegele, M.L. Ruffo, and F.E. Below. 2013. Nutrient Uptake, Partitioning, and Remobilization in Modern, Transgenic Insect-Protected Maize Hybrids. Agron. J. 105: 161-170.
-Bennett, E.M., S.R. Carpenter, and N.F. Caraco. 2001. Human Impact on Erodable Phosphorus and Eutrophication: A Global Perspective.
-Bruinsma, J. 2009. The resource outlook to 2050: by how much do land, water and crop yields need to increase by 2050? FAO expert meeting on how to feed the world in 2050, Rome, Italy. 24–26 June 2009. Food and Agriculture Organization, Rome, Italy.At: *ftp://ftp.fao.org/docrep/fao/012/ak542e/ak542e06.pdf* (accessed: 1/29/2017)
-Bruns, H.A., and M.W. Ebelhar. 2006. Nutrient uptake of maize affected by nitrogen and potassium fertility in a humid subtropical environment. Commun Soil Sci. Plant 37*:* 275–293.
-Cassman, K.G. 1999. Ecological intensification of cereal production systems: Yield potential, soil quality, and precision agriculture. Proc. Natl. Acad. Sci. USA 96: 5952-5959.

-Ebelhar, S.A., and E.C. Varsa. 2000.Tillage and potassium placement effects on potassium utilization by corn and soybean. Commun Soil Sci Plant 31: 11–14.

-Egli, D. B. 1998. Seed Biology and the yield of grain crops. CAB International, Wallingford, UK. 178 p.

-Evans, L.T. 1993. Crop evolution, adaptation, and yield. Cambridge Univ. Press, Cambridge, UK.

-FAO. 2009. How to feed the world in 2050. Proceedings of the expert meeting on how to feed the world in 2050, Rome, Italy. 24–26 June 2009. Food and Agriculture Organization, Rome, Italy.

-Glaab, J., and W.M. Kaiser. 1999. Increased nitrate reductase activity in leaf tissue after application of the fungicide kresoxim-methyl. Planta 207: 442-448.

-Grant, C.A., Wu, R., Selles, F., Harker, K.N., Clayton, G.W., Bittman, S., and Lupwayi, N.Z. 2012. Crop yield and nitrogen concentration with controlled release urea and split applications of nitrogen as compared to non-coated urea applied at seeding. Field Crop Res.127: 170-180.

-Harder, H.J., R.E. Carlson, and R.H. Shaw. 1982. Corn Grain Yield and Nutrient Response to Foliar Fertilizer Applied during Grain Fill1. Agron. J. 74:106-110.

-Heckman, J.R., and E.J. Kamprath. 1992. Potassium accumulation and corn yield related to potassium fertilizer rate and placement. Soil Sci 56: 141–148

-Heckman, J.R., J.T. Simons, D.B. Beegle, F.J. Coale, S.J. Herbert, T.W. Bruulsema, and W.J. Bamka. 2003. Nutrient removal by corn grain harvest. Agron. J. 95: 587-591

-Kruk, B., and E.H. Satorre. 2003. Densidad y arreglo especial del cultivo. En: A.J. Pascale (ed), Producción de granos: bases funcionales para su manejo. Editorial Facultad de Agronomía, Universidad de Buenos Aires. Buenos Aires. p. 277-316.

-Laboski, C.A.M., J.B. Peters, and L.G. Bundy. 2006. Nutrient application guidelines for field, vegetable, and fruit crops in Wisconsin. Pub. A2809. Cooperative Extension, University of Wisconsin.

-Major, D.J., B.W. Beasley, and R.I. Hamilton. 1991. Effect of maize maturity on radiation-use efficiency. Agron. J. 83: 895-903.

-Mallarino A.P., J.M. Bordoli, and R. Borges. 1999. Phosphorus and potassium placement effects on early growth and nutrient uptake of no-till corn and relationships with grain yield. Agron J 91: 37–45

-Mueller, N.D., J.S. Gerber, M. Johnston, D.K. Ray, N. Ramankutty, and J.A. Foley. 2012. Closing yield gaps through nutrient and water management. Nature 490: 254-257.

-Nafziger, E.D. 1994. Corn planting date and plant population. J. Prod. Agric.7:59-62.

-Nason, M.A., Farrar, J., and Bartlett, D. 2007. Strobilurin fungicides induce changes to photosynthetic gas exchange that do not improve water use efficiency of plants grown under conditions of water stress. Pest Manage. Sci. 63:1191-1200.

-Paul, P.A., L.V. Madden, C.A. Bradley, A.E. Robertson, G.P. Munkvold, G. Shaner, K.A. Wise, D.K. Malvick, T.W. Allen, A. Grybauskas, P. Vincelli, and P. Esker. 2011. Meta-Analysis of Yield Response of Hybrid Field Corn to Foliar Fungicides in the U.S. Corn Belt. Phytopathology, 101: 1122-1132.

-Puckridge, D.W., and C.M. Donald. 1967. Competition among wheat plants sown at a wide range of densities. Aust. J. Agric. Res. 18:193-211.

-Royal Society. 2009. Reaping the benefits: science and the sustainable intensification of global agriculture. RS Policy document 11/09, Royal Society, London.

-Ruffo, M.L., L.F. Gentry, A.S. Henninger, J.R. Seebauer, and F.E. Below. 2015. Evaluating management factor contributions to reduce corn yield gaps. Agron. J. 107: 495-505.

-Satorre, E.H. 1999. Plant density and distribution as modifiers of growth and yield. In: E.H. Satorre, and G.A. Slafer (eds), Wheat: ecology and physiology of yield determination. The Haworth Press, Inc. New York, London, Oxford. p. 141-159.

-Scharf, P. C., W. J. Wiebold, and J. A. Lory. 2002. Corn Yield Response to Nitrogen Fertilizer Timing and Deficiency Level. Agron. J. 94:435-441.

-Sharpley, A. N., S. C. Chapra, R. Wedepohl, J. T. Sims, T. C. Daniel, and K. R. Reddy. 1994. Managing agricultural phosphorus for protection of surface waters: Issues and options. J. Environ. Qual 23:437–451.

-Tetio-Kagho, F., and F. Gardner. 1988. Responses of maize to plant population density. I. Canopy development, light relationships, and vegetative growth. Agron. J. 80:930-935.

-Tilman, D., C. Balzer, J. Hill, and B.L. Befort. 2011. Global food demand and the sustainable intensification of agriculture. Proc. Natl. Acad. Sci. USA 108: 20260-20264.

-Tokatlidis, I.S., and S.D. Koutroubas. 2004. A review of maize hybrids' dependence on high plant populations and its implications for crop yield stability. Field Crops Res. 88:103-114.

-Tollenaar, M., and T.W. Bruulsema. 1988. Efficiency of maize dry matter production during periods of complete leaf area expansion. Agron. J. 80: 580-585.

-Tomar, J.S., A.F. MacKenzie, G.R. Mehuys, and I. Alli. 1988. Corn Growth with Foliar Nitrogen, Soil-Applied Nitrogen, and Legume Intercrops. Agron. J. 80:802-807.

-Torbert, H.A., K.N. Potter, and J.E. Morrison. 2001. Tillage System, Fertilizer Nitrogen Rate, and Timing Effect on Corn Yields in the Texas Blackland Prairie. Agron. J. 93:1119-1124.

-UN. 2015. World population prospects: the 2015 revision, key findings & advance tables. United Nations. Department of Economic and Social Affairs. Population Division. Working Paper No. ESA/P/WP.241. United Nations, New York.

-U.S. Census Bureau. 2017. International Programs Data Base. At:*http://www.census.gov/population/international/data/worldpop/table_population.php* (updated: 9/27/2016; accessed: 1/8/2017).

-Westgate, M.E., F. Forcella, D.C. Reicosky, and J. Somsen. 1997. Rapid canopy closure for maize production in the northern US corn belt: Radiation-use efficiency and grain yield. Field Crop Res. 49: 249-258.

-Wik, M., P. Pingali, and S. Broca. 2008. Global Agricultural Performance: Past Trends and Future Prospects. Background Paper for the World Development Report 2008. World Bank, Washington, DC.

-Wortmann, C.S., A.R. Dobermann, R.B. Ferguson, G.W. Hergert, C.A. Shapiro, D.D. Tarkalson, and D.T. Walters. 2009. High-Yielding Corn Response to Applied Phosphorus, Potassium, and Sulfur in Nebraska. Agron. J. 101: 546-555.

Table 1. Detail of the soil series and corn management practices performed in the period 2012-2014 in the corn ecological intensification study in Virginia.

	New Kent 2012		**Virginia Beach 2013**		**New Kent 2013**		**New Kent 2014**		**Northumberland 2014**	
Management system	**FS †**	**EI †**	**FS**	**EI**	**FS**	**EI**	**FS**	**EI**	**FS**	**EI**
***Baseline management practices* ‡**										
Pre-plant base fertilization date	25-Apr		4-May		4-May		28-Apr		24-Apr	
$N–P_2O_5–K_2O$, kg ha^{-1}	17-90-67		45-67-67		17-90-67		17-90-67		34-67-67	
Seeding date	25-Apr		15-Apr		24-Apr		28-Apr		24-Apr	
Treatment management practices										
Seed rate, seeds ha^{-1}	67,000	79,000	89,000	101,000	67,000	79,000	67,000	79,000	89,000	101,000
Sidedress N rate, kg ha^{-1}	112	45 x 3	112	45 x 3	112	45 x 3	112	45 x 3	112	45 x 3
Topdress P_2O_5, kg ha^{-1}	none	56	none	56	none	56	none	56	none	56
Topdress K_2O, kg ha^{-1}	none	84	none	84	none	84	none	84	none	84
CoRon Foliar triazole N, kg ha^{-1} €	none	22	none	22	none	22	none	22	none	22
Headline, l ha^{-1} ƛ	none	0.94	none	0.94	none	0.94	none	0.94	none	0.94

† FS: Farmer Standard; EI: Ecological Intensification.

‡ General management practices applied at same rates and dates for both FS and EI management systems in all sites-years, and thus, not considered as factors under analysis.

€ Total Nitrogen (N): 25% (12.5% as Urea N and 12.5% as water soluble N); Iron (Fe): 0.5% chelated Fe.

ƛ Pyraclostrobin (13.64%) carbamic acid, [2-[[[1-(4-chlorophenyl)-1H-pyrazol-3-yl]oxy]methyl]phenyl]methoxy-, methyl ester; Metconazole (5.14%) 5-[(4-chlorophenyl)methyl]-2,2-dimethyl-1-(1H-1,2,4-triazol-1-ylmethyl)cyclopentanol)

Table 2. Detail of the treatments under analysis in the period 2012-2014 in the corn ecological intensification study in Virginia.

Treatment		Seed rate ha^{-1}	P_2O_5 †	K_2O †	N †	Foliar N	Foliar fung
1	**FS**	67,000 or 89,000	NO	NO	V4	NO	NO
2	High seed rate	**79,000 or 101,000**	NO	NO	V4	NO	NO
3	Add 56 kg/ha P_2O_5	67,000 or 89,000	**+ 56**	NO	V4	NO	NO
4	Add 84 kg/ha K_2O	67,000 or 89,000	NO	**+ 84**	V4	NO	NO
5	Split N	67,000 or 89,000	NO	NO	**V4, V6 and V10**	NO	NO
6	Add foliar N	67,000 or 89,000	NO	NO	V4	**YES**	NO
7	Add foliar fung	67,000 or 89,000	NO	NO	V4	NO	**YES**
8	**EI**	79,000 or 101,000	+ 56	+ 84	V4, V6 and V10	YES	YES
9	Low seed rate	**67,000 or 89,000**	+ 56	+ 84	V4, V6 and V10	YES	YES
10	Drop 56 kg/ha P_2O_5	79,000 or 101,000	**NO**	+ 84	V4, V6 and V10	YES	YES
11	Drop 84 kg/ha K_2O	79,000 or 101,000	+ 56	**NO**	V4, V6 and V10	YES	YES
12	Single N	79,000 or 101,000	+ 56	+ 84	**V4**	YES	YES
13	Drop foliar N	79,000 or 101,000	+ 56	+ 84	V4, V6 and V10	**NO**	YES
14	Drop foliar fung	79,000 or 101,000	+ 56	+ 84	V4, V6 and V10	YES	**NO**

† N-P-K base fertilization at planting for all plots.

Table 3. Summary of effects for the corn ecological intensification study inVirginia. Numerical values indicate the grain yield difference between Farmer Standard (FS) system (treatment 1) and single factors added to it (treatment 2 through 7) or Ecological Intensification (EI) system (treatment 8) and single factors removed from it (treatments 9 through 14). No significant differences are indicated by ns.

Treatment		**Seed rate ha^{-1}**	**P_2O_5**	**K_2O**	**N**	**Foliar N**	**Foliar fung**
1	FS	ns	ns	ns	ns	ns	ns
2	High seed rate	**+ 605; + 2487;- 2521**	ns	ns	ns	ns	ns
3	Add 56 kg/ha P_2O_5	ns	ns	ns	ns	ns	ns
4	Add 84 kg/ha K_2O	ns	ns	**- 3533**		ns	ns
5	Split N	ns	ns	ns	**+ 1112**	ns	ns
6	Add foliar N	ns	ns	ns	ns	**+ 1318**	ns
7	Add foliar fung	ns	ns	ns	ns	ns	ns
8	EI	ns	ns	ns	ns	ns	ns
9	Low seed rate	ns	ns	ns	ns	ns	ns
10	Drop 56 kg/ha P_2O_5	ns	ns	ns	ns	ns	ns
11	Drop 84 kg/ha K_2O	ns	ns	ns	ns	ns	ns
12	Single N	ns	ns	ns	**- 6468**	ns	ns
13	Drop foliar N	**+ 363**	ns	ns	ns	ns	ns
14	Drop foliar fung	ns	ns	ns	ns	ns	ns

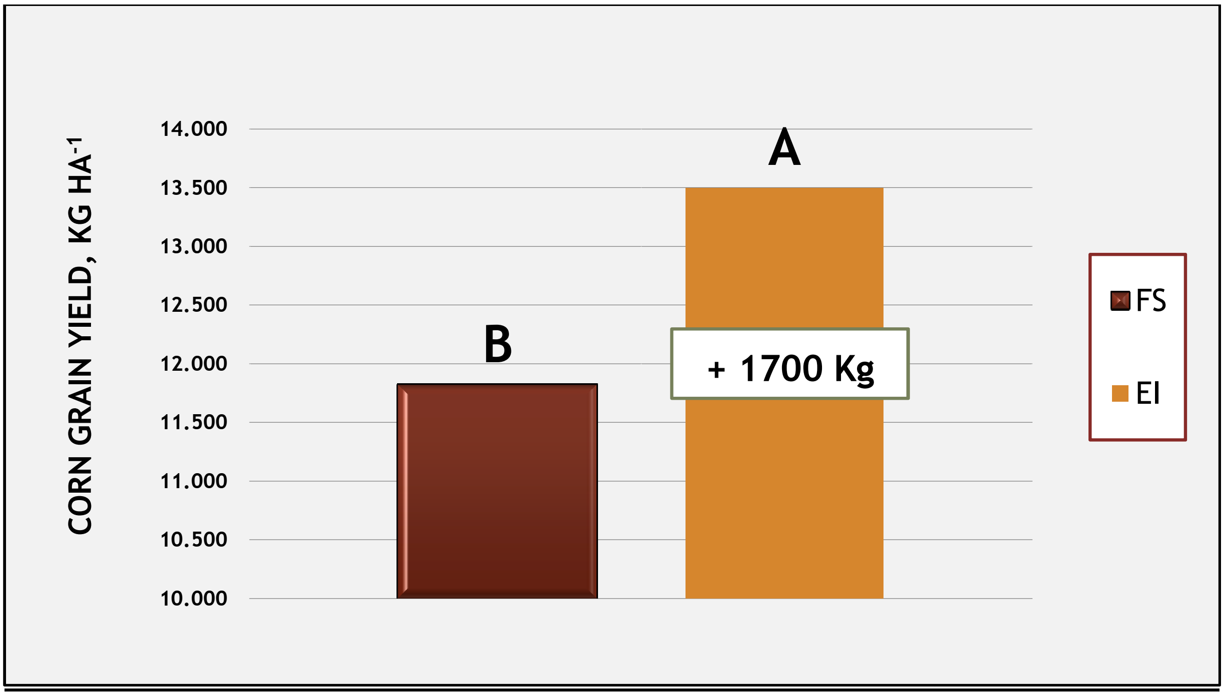
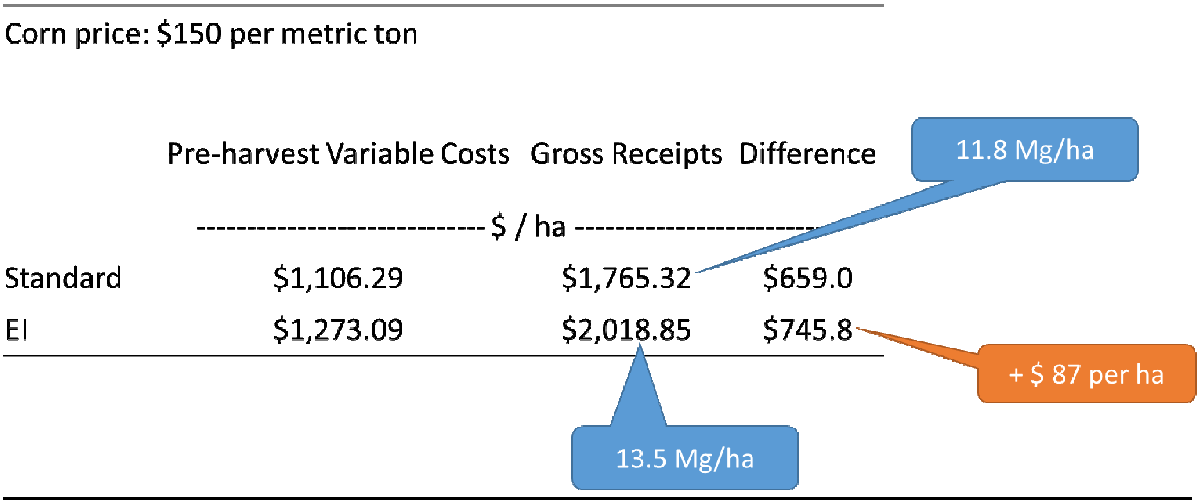


Figure 1. Comparison of the full farmer standard (FS) (treatment 1) and ecological intensification (EI) system (treatment 8) across locations-years.



Corn price: $150 per metric ton

	Pre-harvest Variable Costs	Gross Receipts	Difference
	---------------------------- $ / ha	-------------------------	
Standard	$1,106.29	$1,765.32	$659.0
EI	$1,273.09	$2,018.85	$745.8

Figure 2. Economic analysis between the full farmer standard (FS) (treatment 1) and ecological intensification (EI)