IMPACT OF VARIABLE RATE FERTILIZATION ON NUTRIENTS LOSSES IN SURFACE RUNOFF FOR WILD BLUEBERRY FIELDS

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ABSTRACT

Wild blueberry producers apply agrochemicals uniformly without considering substantial variation in soil properties, topographic features that may affect fruit yield within field. A wild blueberry field was selected to evaluate the impact of variable rate (VR) fertilization on nutrient losses in surface runoff from steep slope to low lying areas to improve crop productivity. Field was divided into three sections (variable rate application, VRA; uniform application, UA; and control) and three management zones (steep slope, Z1; moderate, Z2 and low lying area, Z3) were developed in each section based on slope variation and bare spots in the field. GPS-guided prescription map was developed in ArcGIS 9.3 to apply fertilizer rates (200,150 and 100 kg ha^{-1} for Z1, Z2, Z3, respectively) with VR fertilizer spreader and zero rate was allocated for bare spots. One section received the growers uniform fertilizer rate of 200 kg ha^{-1} for comparison. USDA-NRCS runoff plots were installed to collect surface runoff samples from different zones of the field. The surface runoff samples were collected from USDA-NRCS runoff plots after every heavy rainfall event and analyzed for total phosphorus (TP), dissolved reactive phosphorus (DRP), and inorganic nitrogen concentrations. The leaf samples were analyzed for leaf nutrient concentrations under VRA and UA. The VRA significantly ($p \leq 0.05$) decreased TP, DRP, and inorganic nitrogen losses in surface runoff as compared to UA in low lying area of the field. Most leaf nutrient concentrations were not significantly influenced by the VRA and were within the recommended optimal ranges. VRA used 40% less fertilizer than standard UA and could improve crop productivity.

Keywords: Variable rate, nutrients losses, surface runoff, leaf nutrients, wild blueberry

INTRODUCTION

Wild blueberry fields have gentle to severe topography (Zaman et al., 2010), therefore, the risk of nutrient runoff from fields increases with the steepness of the slope (Zheng, 2005). Establishment and maintenance of wild blueberry fields require substantial inputs including nutrients, and herbicides (Travett, 1962). Excessive supply of nutrients risks ground and surface water quality. There is an increasing concern on proper agricultural management including nutrient, soil, and water, to minimize the point sources of pollution contaminating (Santhi et al., 2006). This requires quantifying the nutrients loss in the surface runoff and the impact of VR fertilization on surface water quality (Harmel et al., 2004).

Surface runoff from agricultural fields consists of N and P. To date, no research has been conducted to investigate P losses in the surface runoff from the wild blueberry fields. Phosphorus is the major element found in the surface runoff samples from the agricultural fields (Sharpley et al., 1987). The phosphorus is present in form of dissolve reactive phosphorus (DRP) and particulate phosphorus (PP) in the surface runoff. Leaching of P is negligible in most soils and P mostly accumulates in surface soil layers, due to its chemistry (Kleinman et al., 2003). P concentrations in soils are inherently low and are a limiting factor for plant growth and development and crop production, as P is an essential element for all living organisms. A major portion of the fertilizer applied in the wild blueberry fields is phosphorus (P) (70 kg ha^{-1}) in form of Di-ammonium phosphate (NPK: 18 – 46 – 0) (Percival and Sanderson, 2004). The other essential and limiting nutrient in the soil is nitrogen (N), which is applied in the form of ammonium sulphate (NPK: 21 – 0 – 0) in the wild blueberry fields. Because of the acidic nature of the wild blueberry soils, nitrification process is slow and chances of presence of ammonium nitrogen are more than nitrate in surface runoff.

Researchers have found that the nutrients level is higher in the low lying areas of the wild blueberry fields (Eaton, 1988; Zaman et al., 2010). Zaman et al. (2009) investigated the relationship of soil nutrients and plant growth and suggested that the field slope can be used as a variable to apply VR fertilization. The introduction of precision agriculture technologies in agricultural fields helps the producers to supply nutrients to soil according to the plant nutrient requirements. The VR fertilizer spreaders are readily available and are replacing the conventional spreaders. No intention has been paid on the VR fertilization in the wild blueberry fields. It is hypothesized that VR fertilization in the wild blueberry fields having substantial variation in slope can reduce the nutrients loss in the surface runoff as compared to uniform fertilization.

MATERIAL AND METHODS

Site Selection

A wild blueberry fields was selected in central Nova Scotia to evaluate the effect of variable rate (VR) fertilization on nutrient losses in surface runoff and leaf nutrients. The selected site was the Cattle Market Field (45^0 22’ 37” N and 63^0 13’ 7” W), Nova Scotia. This field was in its vegetative year in 2011. The Cattle Market Field was divided into three sections, one section received VR fertilization, second section received uniform fertilization, and no fertilization was applied in third section (control section). The soil at the experimental site was classified as sandy loam (Orthic Humo-Ferric Podzols), which is a well-drained acidic soil (Webb et al., 1991).

Slope Data and Map

Slope variability was assessed with a slope measurement and mapping system (SMMS) at the start of the experiment in sprout year for Cattle Market Field. The system consists of a tilt sensor that determines the tilt of the vehicle in any orientation on the slope. The location of the data points were determined using a Trimble AgGPS-332 DGPS antenna (Trimble Navigation Limited, CA, USA) mounted on the all-terrain vehicle (ATV) to determine. A laptop computer, with a custom developed software, recorded georeferenced slope data from the tilt sensor and GPS in real-time within the field (Fig. 1). Detailed procedures for measurement and mapping of slope are outlined in Zaman et al. (2010).

Slope map of Cattle Market Field was generated in Arc GIS 9.3 software using kriging interpolation technique. Geostatistical analysis was performed using GS+ Geostatistics for the Environmental Sciences Version 9 software (Gamma Design Software, LLC, MI, USA) to measure nugget, sill and range of influence. These semiveriogram parameters were used in kriging interpolation technique to generate smooth krigged slope maps. The bare spots, weeds and grasses were also mapped in the field using Topcon HiPer Lite+ RTK-GPS (Topcon positioning Sys., Inc., CA, USA). The Cattle Market Field was divided into three slope categories ranged from 0-12 %, 12-24 %, and >24 % (Fig. 2).

Variable Rate Fertilization

Three different management zones were delineated based on variation in slope (zone-1 (Z1), >24% slope; zone-2 (Z2), 12 – 24% slope; and zone-3 (Z3), 0 – 12% slope) within the selected field. Prescription map was generated for VR fertilization in developed management zones of VR section. The 7.32 meters wide boom Valmar 1255 pull type granular applicator (Valmar Airflo Inc. MB, Canada) equipped with Rawson™ Accu-Rate® variable rate controller system(Trimble Navigation Ltd. CA, USA), GPS and an electro hydraulic

Fig. 1. Slope Measuring and Mapping System (Zaman et al., 2010).

metering drive unit was utilized to apply different fertilizer rates in management zones within Cattle Market Field.The fertilizer (NPK: 16.5 – 34.5 – 4.5, respectively), constituted of ammonium sulphate (NPK: 21 – 0 – 0), di-ammonium phosphate (NPK: 18 – 46 – 0), muriate of potash (NPK: 0 – 0 – 60), was applied in the third week of May 2011 for Cattle Market Field, during the sprout year. In the VR section of the field, the highest N rate, equals to the grower's uniform rate (200 kg ha^{-1}), was allocated to the Z1, and the remaining two management zones received diminishing amounts of N down to a minimum of 50% of the maximum (Fig. 2 and 3).

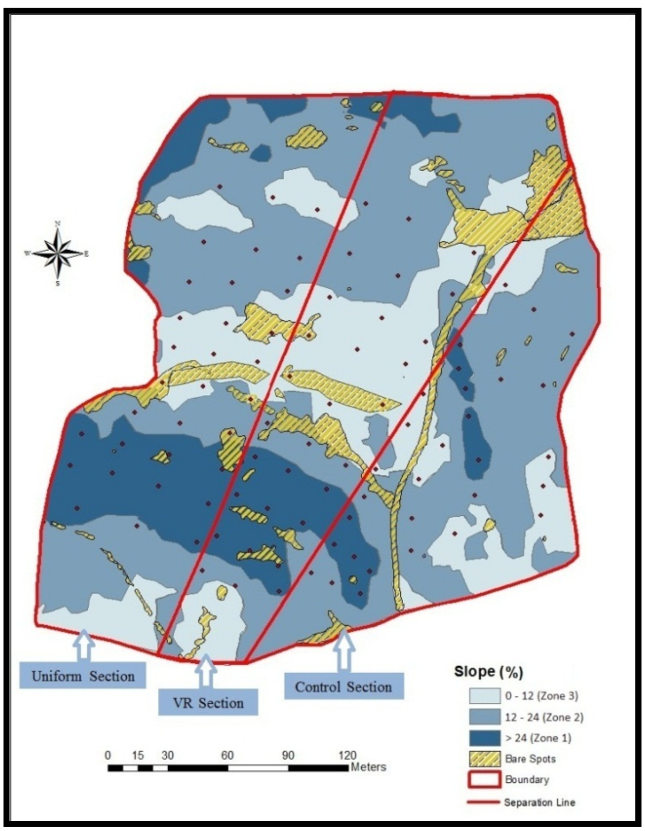

Fig. 2. Slope zones and sampling point locations for Cattle Market Field.

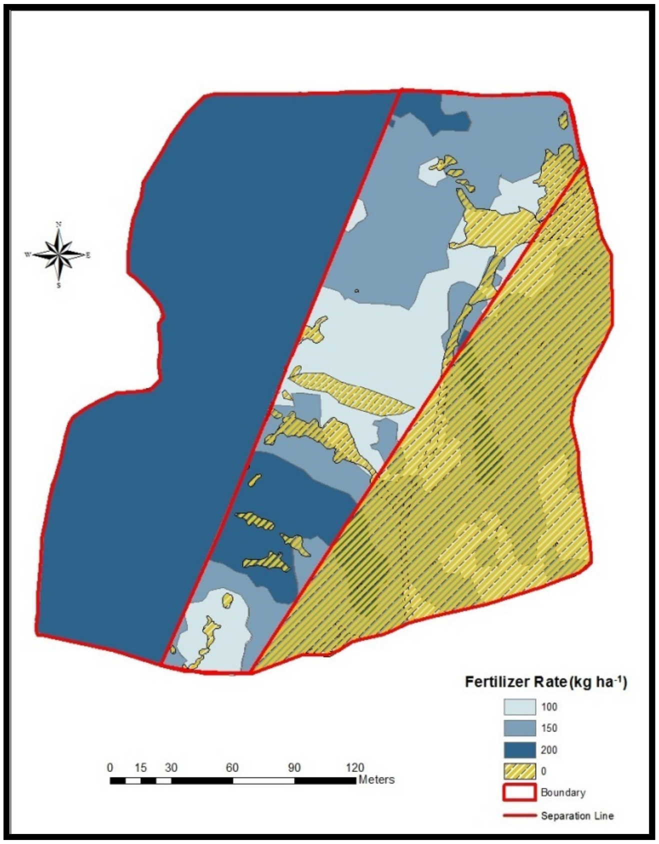

Fig. 3. Prescription map generated in ArcGIS for VR fertilization in Cattle Market Field

Bare spots were defined as a separate class in the developed management zones and zero rates was applied in bare spots of the VR section. These rates were selected on the basis of results of Zaman et al. (2009), who found that excessive leaf nutrients and vegetative growth, and less fruit yield was observed in low lying areas of the field as compared to steep slope areas. The grower's uniform fertilizer rate 200 kg ha^{-1} was applied in uniform fertilizer section in all management zones and bare spots for comparison. No fertilizer was applied in the control section of Cattle Market Field as shown in Fig. 3.

USDA-NRCS runoff plots

USDA-NRCS runoff plots were placed in the Cattle Market Field to measure the surface runoff volumes from known areas in each management zone (Fig. 4). The locations of these USDA plots were determined on the basis of contour map. Micro topography of the catchment areas was conducted using a RTK-GPS to determine the area of the USDA runoff plots. Total area and average slope of the catchment was used to calculate the catchment areas of runoff collectors using eq. 1 (Tomer et al., 2003):

$$E = \left[\frac{A}{22.13}\right]^{0.6} \times \left[\frac{Sin \propto}{0.0896}\right]^{1.3} \quad (1)$$

Where E = Catchment area of the runoff plot (m^2),
A = Total catchment area (m^2), and
α = Average slope of the area (degrees)

The descriptions of USDA-NRCS plots are provided (Table 1). The USDA runoff plots VRO, UNO, and CTO were open from the top to collect combine runoff from all three management zones, while other runoff plots were closed from the upstream end.

Construction of runoff plots

First, wooden sheets (2.44×1.52 m) were cut into variable size lengths and 0.3 m width boards. Trenches were dug in the ground, and boards were placed at appropriate locations at a depth of 0.15 m below the ground surface in order to avoid entry of flow from the outside of the constructed plots.

Collections buckets were placed at the end of each runoff plot to collect the surface runoff from the plot areas. These buckets were covered with plastic sheets to block the direct rainfall or other debris from entering into the buckets. After every rainfall event the runoff samples were collected from June to October 2011. Runoff samples from every plot were immediately stored into the refrigerator for further analysis. The schematic diagram of the USDA runoff plot shows the mechanism of runoff collection (Fig. 5).

Table 1. Description of USDA-NRCS runoff plots in the Cattle Market Field.

USDA-NRCS Plot	Description	Area (m^2)
CTS	USDA Runoff plot in Z1 of control section; closed	57.00
CTM	USDA Runoff plot in Z2 of control section; closed	45.75
CTL	USDA Runoff plot in Z3 of control section; closed	8.15
CTO	USDA Runoff plot in Z3 of control section; open	41.00
VRS	USDA Runoff plot in Z1 of VR section; closed	97.00
VRM	USDA Runoff plot in Z2 of VR section; closed	44.20
VRL	USDA Runoff plot in Z3 of VR section; closed	30.00
VRO	USDA Runoff plot in Z3 of VR section; open	60.86
UNS	USDA Runoff plot in Z1 of uniform section; closed	96.50
UNM	USDA Runoff plot in Z2 of uniform section;	47.90

	closed	
UNL	USDA Runoff plot in Z3 of uniform section; closed	14.00
UNO	USDA Runoff plot in Z3 of uniform section; open	52.30

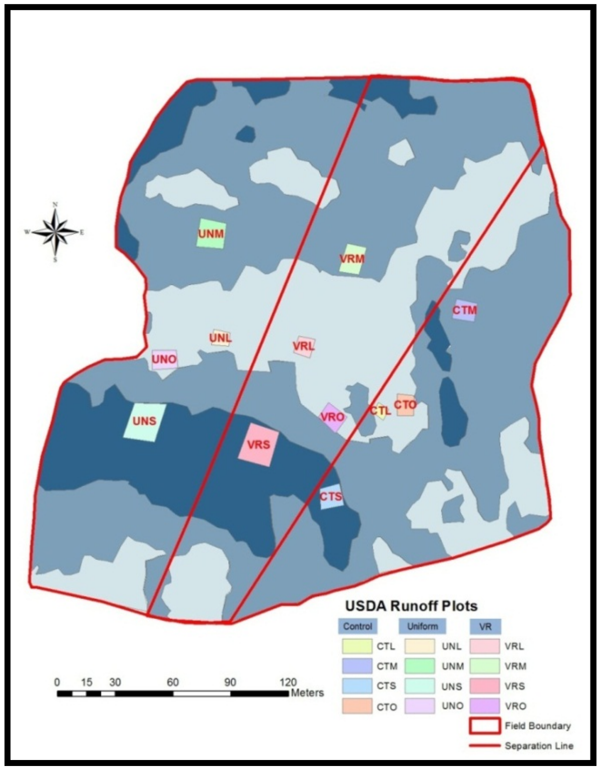

Fig. 4. Locations of USDA runoff plots to collect surface runoff samples from different management zones in the Cattle Market Field.

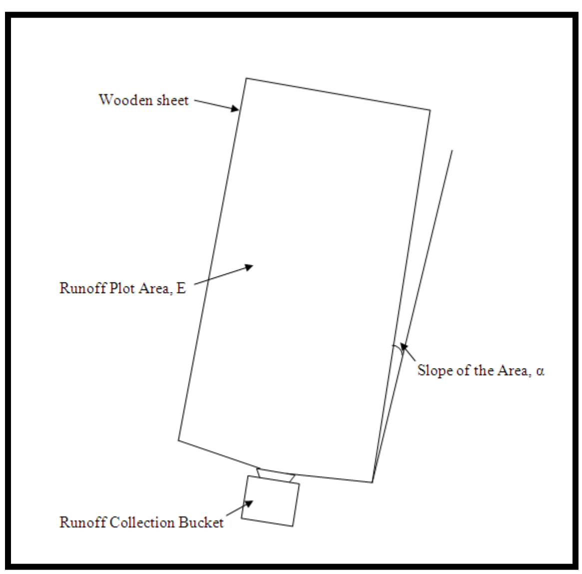

Fig. 5. Schematic diagram for USDA-NRCS runoff plots.

Surface runoff sample analysis

The surface runoff samples were analyzed for total phosphorus (TP), dissolved reactive phosphorus (DRP) and inorganic nitrogen. TP was analyzed using total a phosphorus channel in a Technicon auto-flow analyzer (Technicon Autoanalyzer-2, NY, USA) and surface runoff samples were filtered using 0.45 μm filter paper and analyzed to quantify DRP (Edwards and Withers, 1998).

Leaf Sampling

Leaf sampling was performed in 3rd week of July at tip-dieback stage during sprout year in each slope zone of the Cattle Market Field to determine the impact of VR and uniform fertilization on wild blueberry leaf nutrients. The wild blueberry leaves were collected at four to six locations at each sampling point (Fig. 3 and 4) from 20 randomly selected blueberry plants to cover variability. The leaf samples were analyzed for micro- and macro- nutrients using inductivity coupled plasma emission spectrometry (ICPES) (Percival and Prive, 2002). The concentration of leaf N was determined using a LECO-CNS-1000 (LECO Corporation, Michigan, USA).

STATISTICAL ANALYSIS

The surface runoff samples were analyzed for TP, DRP, and inorganic nitrogen by using repeated measure analysis of variance (RM ANOVA) using SAS statistical software (SAS Institute, Cary, N.C.) by using mixed-model procedure and significance probability (P) of 5 %, in order to compare the potential impacts that VR fertilization or uniform fertilization have on the nutrient losses in surface runoff. The assumptions of normality of residuals were verified using Shapiro-Wilk test. The data for leaf nutrients was analyzed by using PROC MIXED and means were separated using LSD method.

RESULTS AND DISCUSSION

The results showed that TP and DRP losses in the samples collected from USDA-NRCS runoff plots were significantly different for VR, uniform, and control treatments (Tables 2 and 3). The VR treatment showed 7.16 % and 11.37 % lower TP and DRP losses as compared to uniform treatment for USDA runoff plots placed in Z1, while control treatment showed negligible losses for TP and DRP in Z1 as compared to VR and uniform treatment. The results suggested that TP losses for VR treatment were 28.80 %, 42.61 %, and 38.50 % lower than uniform treatment in samples collected from USDA plots placed in Z2, Z3 and combine, respectively. Throughout the monitoring period, the TP and DRP losses in surface runoff showed decreasing trends among all three treatments and slope zones as indicated by the interaction of sampling date, slope zone and fertilizer treatment. The total phosphorus losses for VR and uniform treatments were 1.43

% and 2.22 %, respectively, of the total phosphorus applied in wild blueberry fields (70 kg ha^{-1}) (Tables 2 and 3).

The losses of DRP in surface runoff for current study were in agreement with the studies of different researchers on different cropping systems such as turfgrass and corn (Heathwaite et al., 1998; Wilcock et al., 1999). Runoff DRP is usually higher from bushes and pastures than from cropland, due to the filtration effect of the vegetation on suspended particles high in particulate phosphorus (PP) (Hollman, 2006), similar to the findings of current study. The amount of DRP decreased later in the study period and PP contributed most of the TP loss from the field. The reason for less DRP was might be due to plant utilization. The higher PP losses in surface runoff as compared to DRP might be due to the fact that PP is mostly insoluble and not readily available for plant uptake.

The inorganic nitrogen losses were similar between uniform and VR treatments for USDA-NRCS in Z1, while significant differences were observed in all other USDA-NRCS runoff plots. The cumulative inorganic nitrogen losses in combine zone were 2.17, 4.02, and 0.41 kg ha^{-1} for VR, uniform, and control treatments. In general, the losses of inorganic nitrogen were high at the start of the experiment. The amount of inorganic nitrogen in surface runoff rapidly decreased after the second rainfall (Table 4). Overall the inorganic nitrogen losses in surface runoff showed decreasing trends throughout the growing season (Table 4). The inorganic nitrogen losses in the combine zone were in combine zone 0.61, 1.02, and 0.08 kg ha^{-1} for VR, uniform, and control treatments in June 15, 2011 rainfall event, which decreased to 0.08, 0.18, and 0.03 kg ha^{-1} for VR, uniform, and control treatments after October 2, 2011 rainfall event. The decrease in inorganic nitrogen losses might be due to utilization of nitrogen by plants, absorption in soil, and nitrogen leaching. These results are in agreement with the results of the study conducted in pasture fields (Kuykendall et al., 1999).

Leaf macro nutrients (N, P, K) were significantly different for uniform, VR, and control treatments in the Cattle Market Field (Table 5). The VR treatment showed significantly lower leaf N concentrations in Z2 and Z3 as compared to uniform treatment, while non-significant differences were observed in Z1 for both VR and uniform treatments. The leaf N concentrations for VR treatment in all slope zones were also within the proposed standards by Trevett (1972). The leaf N concentrations in Z2 and Z3 for uniform treatment were more than proposed leaf standards. The mean leaf N concentrations in Z2 and Z3 for VR treatment were 1.93 and 1.97 %, respectively, while leaf N concentrations were 2.07 and 2.29 % in Z2 and Z3 for uniform treatment, respectively (Table 5). The lower rates of applied fertilizer in Z2 and Z3 of VR treatment could be the reason of these significant differences.

Leaf N concentrations for control treatment were less than proposed standards by Trevett (1972) except in Z3, where it was within standard values. Repeated applications of fertilizers in lowbush blueberry fields could result in increases levels of leaf macro nutrients especially in the low lying areas of the field. The results were in agreement with findings of Eaton and Patriquin (1989). Leaf P and K concentrations showed similar trends. Leaf Ca, Mg, Fe and Mn were within proposed standards in all slope zones for both uniform and VR treatments (Table 5). These results were similar to the finding of Zaman et al.

(2009), they found higher leaf N and P concentrations in the low lying areas of the wild blueberry fields.

The excessive leaf nutrients in Z2 and Z3 of uniform fertilization section of the field indicated that nutrients from the steep slope areas accumulated in the low lying areas with surface runoff. The excessive leaf nutrient can result in excessive vegetative growth, which can reduce the fruit yield.

Table 2. Total phosphorus losses in the surface runoff from the Cattle Market Field for USDA-NRCS runoff plots in 2011.

Slope Zone	USDA Plot	June 15 (g ha^{-1})	July 12 (g ha^{-1})	July 30 (g ha^{-1})	August 02 (g ha^{-1})	August 10 (g ha^{-1})	September 15 (g ha^{-1})	October 02 (g ha^{-1})	Cumulative (g ha^{-1})
Zone 1	VRS	218.2	205.3	160.7	125.2	87.7	28.7	36.3	862.1
	UNS	237.3	216.4	171.1	139.9	91.6	32.9	39.4	928.6
	CTS	8.4	7.1	6.8	5.6	4.5	3.6	3.5	39.5
Zone 2	VRM	173.3	150.6	126.5	103.8	69.3	18.7	12.9	655.1
	UNM	240.1	220.3	168.6	137.1	89.5	28.8	35.6	920
	CTM	9.5	7.1	6.2	5.9	4.9	4.2	3.7	41.5
Zone 3	VRL	145.7	136.1	113.9	82.4	42.1	11.1	7.6	538.9
	UNL	249.1	216.4	182.1	129.6	93.1	35.1	33.6	939
	CTL	9.7	8.5	6.5	6.2	5.6	4.5	3.8	44.8
Combine	VRO	239.1	213.7	173.4	131.0	99.1	39.8	32.4	928.5
	UNO	405.8	352.1	258.8	195.1	148.6	85.2	64.1	1509.7
	CTO	10.7	8.9	6.9	6.1	5.9	4.6	4.2	47.3

RM ANOVA

Effect	DF	F-value	P-value
Fertilization Method (F)	2	40.97	0.0003
Sampling Date	6	145.70	<0.0001
Sampling Date × Fertilization Method (F)	12	36.63	<0.0001

Significant at P < 0.05

Table 3. Dissolved reactive phosphorus losses in the surface runoff from the Cattle Market Field for USDA-NRCS runoff plots in 2011.

Slope Zone	USDA Plot	June 15 (g ha^{-1})	July 12 (g ha^{-1})	July 30 (g ha^{-1})	August 02 (g ha^{-1})	August 10 (g ha^{-1})	September 15 (g ha^{-1})	October 02 (g ha^{-1})	Cumulative (g ha^{-1})
Zone 1	VRS	142.3	110.6	83.4	54.6	36.5	10.8	11.3	449.5
	UNS	157.9	126.4	93.3	60.8	43.3	14.6	10.9	507.2
	CTS	4.1	3.8	2.9	2.6	2.5	1.3	2.5	19.7
Zone 2	VRM	102.7	89.3	65.3	39.5	24.9	7.6	5.9	335.2
	UNM	151.9	130.2	89.4	61.2	37.5	12.1	12.4	494.7
	CTM	4.8	3.7	3.6	2.7	2.6	2.5	2.9	22.8
Zone 3	VRL	95.2	80.3	43.4	35.9	18.6	5.1	3.2	286.1
	UNL	159.6	115.4	96.2	57.8	42.5	15.3	13.4	500.2
	CTL	4.3	3.5	3.4	3.1	2.3	2.1	2.6	21.3
Combine	VRO	140.8	112.3	81.6	55.6	35.6	16.4	12.3	454.6
	UNO	295.3	213.8	130.2	91.3	60.5	30.8	21.6	843.5
	CTO	4.8	3.8	3.4	2.8	3.1	2.6	3.5	24

RM ANOVA

Effect	DF	F-value	P-value
Fertilization Method (F)	2	35.25	0.0005
Sampling Date	6	75.96	<0.0001
Sampling Date × Fertilization Method (F)	12	20.80	<0.0001

Significant at $P < 0.05$

Table 4. Inorganic nitrogen losses in the surface runoff for the USDA Runoff plots from the Cattle Market Field in 2011.

Slope Zone	USDA Plot	June 15 (kg ha^{-1})	July 12 (kg ha^{-1})	July 30 (kg ha^{-1})	August 02 (kg ha^{-1})	August 10 (kg ha^{-1})	September 15 (kg ha^{-1})	October 02 (kg ha^{-1})	Cumulative (kg ha^{-1})
Zone 1	VRS	0.61	0.48	0.41	0.30	0.17	0.12	0.07	2.16
	UNS	0.66	0.55	0.43	0.31	0.16	0.14	0.08	2.33
	CTS	0.07	0.05	0.04	0.05	0.04	0.04	0.02	0.31
Zone 2	VRM	0.48	0.41	0.32	0.27	0.13	0.09	0.05	1.75
	UNM	0.69	0.53	0.46	0.31	0.18	0.15	0.09	2.41
	CTM	0.08	0.05	0.05	0.04	0.04	0.03	0.03	0.32
Zone 3	VRL	0.37	0.33	0.26	0.21	0.09	0.06	0.03	1.35
	UNL	0.73	0.56	0.49	0.32	0.19	0.16	0.10	2.55
	CTL	0.09	0.06	0.05	0.04	0.05	0.04	0.03	0.36
Combine	VRO	0.61	0.51	0.41	0.29	0.16	0.11	0.08	2.17
	UNO	1.02	0.87	0.77	0.58	0.34	0.26	0.18	4.02
	CTO	0.08	0.07	0.09	0.05	0.05	0.04	0.03	0.41

RM ANOVA

Effect	DF	F-value	P-value
Fertilization Method (F)	2	46.40	0.0002
Sampling Date	6	146.63	<0.0001
Sampling Date × Fertilization Method (F)	12	33.15	<0.0001

Significant at $P < 0.05$

Table 5. Effect of VR, uniform, and control fertilization on wild blueberry leaf nutrients in the Cattle Market Field.

Slope Zone	Fertilization Method	N	P	K	Ca	Mg	Fe	Mn
		(%)	(%)	(%)	(%)	(%)	(ppm)	(ppm)
Zone 1	Variable	1.85^{b}	0.123^{b}	0.47^{a}	0.36^{a}	0.19^{a}	37.74^{a}	1650^{a}
	Uniform	1.86^{b}	0.120^{b}	0.48^{a}	0.35^{a}	0.19^{a}	37.85^{a}	1452^{ab}
	Control	1.53^{a}	0.097^{a}	0.36^{b}	0.38^{a}	0.17^{a}	38.34^{a}	1338^{ab}
Zone 2	Variable	1.93^{bc}	0.131^{bc}	0.48^{a}	0.46^{ab}	0.18a	39.91^{a}	1331^{ab}
	Uniform	2.07^{c}	0.137^{c}	0.53^{c}	0.47^{ab}	0.18^{a}	41.34^{a}	1506^{ab}
	Control	1.65^{ab}	0.102^{a}	0.39^{b}	0.40^{a}	0.18^{a}	37.17^{a}	1453^{ab}
Zone 3	Variable	1.97^{bc}	0.143^{d}	0.52^{c}	0.46^{ab}	0.18^{a}	43.79^{a}	1528^{ab}
	Uniform	2.29^{c}	0.155e	0.58^{d}	0.51^{b}	0.19^{a}	40.67^{a}	1502^{ab}
	Control	1.76^{ab}	0.112^{ab}	0.43^{ab}	0.45^{ab}	0.18^{a}	42.34^{a}	1261^{b}
LSD ($p<0.05$)		0.08	0.008	0.03	0.03	0.01	6.90	190.3
Treatment Factor		Mixed ANOVA						
Fertilization Method(F)		***	***	***	*	NS	NS	NS
Slope Zone(S)		***	***	***	*	NS	NS	NS
F x S		NS	***	NS	NS	NS	NS	NS

Means followed by different letters are significantly different at a significance level of 0.05.
*Significant at the 0.05 probability level
** Significant at the 0.01 probability level
*** Significant at the 0.001 probability level
NS = Non-significant

CONCLUSIONS

The VR fertilization significantly ($p \leq 0.05$) decreased TP, DRP, and inorganic nitrogen losses in surface runoff samples, collected from USDA-NRCS runoff plots, as compared to the uniform treatment. The DRP was strongly related to TP content and more than 50% of DRP contributed to TP loss in surface runoff. The possible reason for higher DRP losses as compared to PP losses might be low amount of TSS losses in the surface runoff as compared to those for other crops reported in literature due to better crop cover produced by wild blueberry plants. The inorganic nitrogen losses in surface runoff also showed significant differences for all treatments, the losses were very high during early stages of the growing season. Leaf nutrient concentrations (N, P, K) were higher than the maximum ranges for uniformly fertilized section in Z2 and Z3. Others nutrients were within ranges. Due to the significant differences of TP and inorganic nitrogen between uniform treatment and VR treatment from the wild blueberry fields, management efforts to reduce phosphorus and inorganic nitrogen loading in surface runoff from these fields should be directed. Phosphorus and nitrogen are essential elements for wild blueberry plant growth but it should be applied according to plant nutrient requirements. Application of fertilizer based on slope variation of field reduced the concentration of nitrogen and phosphorus in surface runoff. The VR fertilization also reduced 40 % of the fertilizer applied in VR treatment as compared to uniform treatment. The VR has successfully reduced the nutrient losses in surface runoff. Based on the results of this study, it is recommended that fertilizers should be applied in wild blueberry fields on slope basis to increase nutrient uptake efficiency, reduce cost of production and reduce nutrient losses in surface runoff, which can pollute environment.

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