Research Article

Effect of Organic and Inorganic Fertilizer on the Water Use Efficiency and Yield Attributes of Wheat under Heavy Textured Soil

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Abstract | The soils of Dera Ismail Khan (D.I. Khan) are calcareous in nature with low organic matter. The area also falls in hot arid environment where organic amendments and efficient water used to reduce the input cost and improve crop yield. A field experiment was conducted at Arid Zone Research Centre (AZRC), D. I. Khan during year 2014 –15 and 2015–16 to investigate the water use efficiency and response of winter wheat (*Triticum aestivum* L.) crop to organic and inorganic fertilizers on a heavy textured soil. The treatments used in the experiment include compost @5 t ha^{-1}, cattle manure @ 5 t ha^{-1}, compost + cattle manure each @ 2.5 t ha^{-1}, NPK @ 150:120: 90 and control (without amendments), replicated four times. The results revealed that organic and inorganic amendments, irrespective of their kind and combinations, exerted significant ($p \leq 0.05$) variation in plant growth, yield parameters of wheat and water use efficiency. The inorganic fertilizer gave significantly higher total dry matter, grain and straw yield and also due to the greater grain yield the water use efficiency calculated was greater in the NPK treatment. Bulk density, porosity and organic matter were significantly improved by the cattle manure and compost treatments. The moisture content and water holding capacity revealed non – significant effect of the treatments. It may be concluded from the current research that water use efficiency in term of grain yield was higher in the treatment plots receiving mineral fertilizer but compost and manures were comparable and showed significant improvement in the soil properties.

Received | October 14, 2016; **Accepted** | August 10, 2017; **Published** | October 28, 2017
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Citation | A. Subhan., Q.U. Khan., M. Mansoor., M.J. Khan. 2017. Effect of organic and inorganic fertilizer on the water use efficiency and yield attributes of wheat under heavy textured soil. *Sarhad Journal of Agriculture,* 33(4): 582-590.
DOI | http://dx.doi.org/10.17582/journal.sja/2017/33.4.582.590
Keywords | Organic fertilizers, Inorganic fertilizers, Wheat, Water use efficiency, Soil physical properties

Introduction

Water shortage is one of the limiting factors in arid agriculture of Pakistan. Conservation of available moisture for crop is a technique which the farmers follows to attain the maximum possible yield. The higher summer temperatures in the arid regions of Pakistan further aggravate the moisture depletion due to least organic matter content depleted by extensive decomposition rate. Hence, organic amendments incorporation may enhance the organic matter content of the soil leading towards the excessive moisture conservation and plant nutrient availability. The soil temperature is inversely correlated with the organic matter content, so the moisture depletion rate might be decrease with the increased organic matter content.

Different researchers have found that organic manures applied in integration with the inorganic fertilizers gave higher yield than sole chemical fertilizers (Sarwar et al., 2008). Soils of Pakistan are low in organic matter (< 5%) and the application of organic matter and compost may replenishes the soil (Sarwar,

2005). Increase organic matter concentrations in soil have showed to enhance the yield of cereals (Sarwar, 2005), improve soil properties i.e. soil density, soil aeration and enhance the soil water holding capacity for plant growth and root development (Zia et al., 1998). Compost is an important source of plant nutrients as it contains greater organic matter content. Compost along with increment of soil organic matter also improves the physico- chemical attributes of soil and it ultimately results in increased yield of crop.

Wheat (*Triticum aestivum* L.) is an important cereal crop, belong to family *poaceae*. Due to its taste and nutritive value it has become the major staple food of different regions of the world (Slafer et al., 1994). Wheat crop can be adopted to different agro-climatic conditions and it can be successfully grown in most of the countries of the world. It is considered important for protein contents. The world total area under wheat is approximately ten million hectares, and wheat is providing 1/ 5th on an average of total calorific input to the world, by producing six hundred and twenty one million tons of grain to the world's population (Reynolds et al., 2006). It meets about 73% protein and calories of the average diet (Hossain et al., 2003). Food security and energy crisis are the serious challenges that Pakistan is facing due to least food production and growing population @ 2.6 percent per annum (Qazilbash, 2002). Use of mineral fertilizer seems to be a very quick and efficient method but the cost on energy is very high and there are several environmental concerns. There are very little choices available to increase the food production through the use of available resources. Water scarcity is one of the problems which hamper the yield of crops. Special emphasis should be given to the effective use of resources for growing the cereals crops particularly wheat which is of prime importance in the agriculture of Pakistan (Anonymous, 2014).

Keeping in view the importance of organic manures and inorganic fertilizer a study was designed to hypothesize that water use efficiency, growth and yield attributes of wheat and soil properties could be improved with the use of inorganic and organic fertilizers.

Materials and Methods

A field experiment was conducted to study the effect of organic and mineral fertilizers on properties of soil, efficiency of water, growth and yield of wheat during rabi season 2014–15 and 2015–16 at Arid Zone Research Centre, Dera Ismail Khan. Randomized complete block design was used with five treatments viz. T1: compost @ 5 ton ha^{-1}, T2: cattle manure @ 5 ton ha^{-1}, T3: cattle manure + compost @ 2.5 ton ha^{-1}each, T4: NPK @ 150:120:90 kg ha^{-1} and T5: control (no amendments added). Compost was prepared using the city garbage, animal waste, plant litter and rotten fruits and vegetables. Treatments were replicated four times. The plot size was kept 7.2 m^2 and Hashim-2008 variety of wheat was sown. Other cultural practices were kept at par in all treatments. Soil samples prior to the experiment were taken on 5th December, 2014 and was analyzed for various physico – chemical characteristics (Table 1). Post-harvest soil analyses of organic matter content (Nelson and Sommer, 1982), soil moisture content (Reynolds, 1970), water holding capacity, bulk density and soil porosity were determined by the procedure given by Piper (1966). The composition of compost and cattle manure is given in Table 2. The metrological data including the temperature (°C), relative humidity, seasonal rainfall and effective rainfall of the cropped season are presented in Table 3.

Table 1: *Physico – chemical analysis of soil before the experiment*

Parameters	Measures
Soil Texture	Clay
Bulk Density (g cm^{-3})	1.46
pH	8.07
ECe (µSm^{-1})	523
Organic Matter (%)	0.36
$CaCO_3$ (%)	14.45
Total N (%)	0.035
Extractable P (mg kg^{-1})	6.29

Table 2: *Composition of compost from cattle manure*

Parameters	Compost
Moisture (%)	42.1
pH	7.01S
Organic matter (%)	31.29
EC (mScm^{-1})	0.21
Total N (g kg^{-1})	12.23
P_2O_5 (g kg^{-1})	7.24

Table 3: *Meteorological data recorded at AZRC, D.I.Khan, during 2014–2016*

Month	2014-15					2015-16				
	Temperature (°C)		Relative Humidity (%)	Seasonal Rainfall (mm)	Effective Rainfall (mm)*	Temperature (°C)		Relative Humidity (%)	Seasonal Rainfall (mm)	Effective Rainfall (mm)*
	Max	Min				Max	Min			
Dec.	20	5	81	-		22	5	76	4	3.76
Jan.	4	5	87	28	26.3	20	4	81	4.4	4.14
Feb.	22	8	84	27	25.4	24	5	63	-	-
Mar.	26	12	84	85	80	32	5	76	95	89.3
April	33	18	71	43	40.42	34	7	75	-	-
Total	-	-	-	**183**	**172**	-		-	**103.4**	**97.2**

Source: *Arid Zone Research Centre, (AZRC), D.I.Khan, KP Pakistan. * Effective Rainfall by USBR method*

Table 4: *Water Use Efficiency of wheat crop calculated in each treatment for year 2014 – 15 and 2015 – 16*

Treatment	Year	No of Irrigation Applied	Irrigation Time (sec)	Discharge (m^3s^{-1})	Area (m^2)	Volume of Water Applied (m^3)	Depth of Water Applied (mm)	Rainfall (mm)	Grain Yield kgm^{-2}	Water Use Efficiency $kgha^{-1}mm^{-1}$
T1: Compost	2014 - 15	4	6000	0.016	45.6	307.2	6736.8	183	1.413	2.09
	2015 - 16	3	6300	0.016	45.6	241.92	5305.2	103.4	1.501	2.82
T2: Cattle manure	2014 - 15	4	6000	0.016	45.6	307.2	6736.8	183	1.103	1.63
	2015 - 16	3	6300	0.016	45.6	241.92	5305.2	103.4	1.216	2.29
T3: Compost +Cattle manure	2014 - 15	4	6000	0.016	45.6	307.2	6736.8	183	1.301	1.93
	2015 - 16	3	6300	0.016	45.6	241.92	5305.2	103.4	1.028	1.93
T4: NPK	2014 - 15	4	6000	0.016	45.6	307.2	6736.8	183	3.887	5.76
	2015 - 16	3	6300	0.016	45.6	241.92	5305.2	103.4	3.97	7.48
T5: Control	2014 - 15	4	6000	0.016	45.6	307.2	6736.8	183	0.8855	1.31
	2015 - 16	3	6300	0.016	45.6	241.92	5305.2	103.4	0.974	1.83

Dates of irrigation water applied during 2014 - 15: 25th December, 2014, 10 January, 17th March and 3rd April, 2015; Dates of irrigation water applied during 2015 - 16: 16th December, 2015, 7th January and 26th February, 2016

The growth and yield parameters of wheat were studied in both years of experiments. The growth parameters included plant height, number of grains per spike, days to heading and number of tiller per plant. While the yield parameters included thousand grain weight, total dry matter yield, grain yield, straw yield were determined. Harvesting of crop was carried out on 20th April, 2015 and 18th April, 2016 for first and second years of experiments respectively. Harvest index was calculated from the data using the following formula (Hühn, 1990).

$$\text{Harvest Index} = \frac{\text{Economic Yield}}{\text{Biological Yield}} \times 100$$

The depth of applied water was measured by cut throat flume method by using the following formula as explained by Hammad et al. (2012):

$$t = (A \times d) \div Q$$

Where
t: Time to irrigation (s)
Q: Discharge ($m^3\ s^{-1}$)
A: Area (m^2)
d: depth of water (mm)
Water Use efficiency was calculated using the formula (Zahoor et al., 2014):

$$\text{Water Use Effeciency } (kgha^{-1}\ mm^{-1}) = \frac{\text{Grain Yield } (kg\ ha^{-1})}{\text{Depth of Water Applied}}$$

Statistical analysis was carried out after the primary data was obtained and subjected to analysis of variance using the software Statistix 9.1 (Steel et al., 1997) and the treatment means were compared using least significant difference (LSD) test at 5% probability level.

Results and Discussion

Water Use Efficiency (WUE):

Water use efficiency is important parameters in the water scarce areas. In the current study the WUE of wheat crop was measured in relation to the organic and inorganic fertilizers (Table 4). The water use efficiency was calculated 6.55 and 9.61 kg $ha^{-1}mm^{-1}$ after the harvest of wheat in 2014–15 and 2015 – 16, respectively in the plots receiving inorganic NPK fertilizers. This might be due to the greater grain yield was obtained where NPK fertilizer was applied. The capacity of the plant to store the moisture would also increase its water use and converting into the yield per unit of water applied (Beheshti and Fard, 2010). Karasahin (2015) reported greater water use efficiency by the use of inorganic fertilizers than the organic manures. Nitrogen fertilizer increases the efficiency of water use by wheat (Deng et al., 2004). The organic amendments were also found to have greater WUE over the control. Yassen et al. (2006) recorded pronounced effect of cattle manure (CM) on enhancing the WUE of grain crops as compared with composted residue of sunflower.

Soil characteristics

The post – harvest bulk density from each plot showed non – significant effect in the first year, while second year showed significant influence on the bulk density of soil (Table 5). The application of organic amendments was effective in reducing the bulk density of soil. The cattle manure gave significantly lower bulk density over the rest of the treatments in the second years.

Soil porosity was influenced significantly by the application of organic and inorganic fertilizer. It was higher in the compost @ 5 t ha^{-1} treatment in the first year, while it was highest in the compost + cattle manure (2.5 t ha^{-1} each) in the second year.

Soil organic matter was also significantly changed by the application of organic manures and compost in both the years of experiment. The highest percent organic matter was recorded in the treatment receiving cattle manure + compost in both the experimental years. The compost and cattle manure applied sole gave significantly lower O.M content, but the residual effect was seen the next year and it yielded higher organic matter in the next experimental year. Water holding capacity and soil moisture content determined in each experiment showed non – significant effect of the treatment during the two years of experiment.

Mbagwu (1992) observed decline in bulk density by applying the rice-shaving and poultry manure. He reported that soil applied with these amendments enhanced the organic matter which reduced the soil compaction. Mbah and Onweremadu (2009) found lower bulk density of soil treated with organic amendments as poultry litter and rice husk over the inorganic fertilization. Sohu et al. (2015) reported greater organic matter content in soil treated with FYM and poultry manure over mineral fertilized with NPK. Also Ghulam et al. (2010) reported similar results with the sugar industry waste.

Growth and yield parameters of wheat

Plant Height: Application of organic and inorganic amendments exerted significant variation in plant height of wheat during both the years (Table 6). In first year the plant height was found greater (91.25 cm) in the plots receiving inorganic fertilizer (NPK). The least plant height of 71.25 cm was found in the control. In the following year, similar trend wwas found, with significantly taller plant of 95.5 cm recorded where inorganic fertilizer was applied @ 150:120:90 kg NPK ha^{-1}. The shortest plants with height of 64 cm were found in the control. Similar results were found by other researchers, for example, Sohu et al. (2015) reported that plant height was significantly higher in the treatments of inorganic fertilizer over organic fertilizers and control. Significantly taller plants have been recorded with the application of inorganic fertilizer and farm yard manure by Muhammad et al. (2014). The highest plants could have been attributed to the greater cell division due to Increased availability of nutrients especially N (Song et al., 2000; Jamil et al., 2004, Iqtidar et al., 2006).

Days to heading: Organic and inorganic treatments showed significant effect on days to heading (Table 6). In the first year of experiment days to heading was found greater (88.5 days) in the plots receiving inorganic fertilizer (NPK). The smallest numbers of days to heading (74.75) were found in the plots, where compost @ 5 t ha^{-1} was applied. In the following year of the experiment almost similar trend was found, with significantly longer time of 120.25 days were recorded in the treatment, where inorganic NPK was applied @ 150:120:90 kg ha^{-1}. It was at par with the

treatment where cattle manure + compost each @ 2.5 t ha^{-1} was applied. The minimum time of 115 days were found in the control, the difference amongst the days to heading is due to the fact that in the first year the sowing was carried out late as compared with the second year sowing.

Table 5: *Soil Parameters as affected by the treatments in each treatment after 2014 – 15 and 2015 – 16*

Treatments	Bulk Density (g cm $^{-3}$)		Soil Porosity (%)		Organic matter (%)		Water Holding capacity (%)		Soil Moisture content (%)	
	2014 – 15	2015 – 16	2014 – 15	2015 – 16	2014 – 15	2015 – 16	2014 – 15	2015 – 16	2014 – 15	2015 – 16
T1: Compost @ 5 t ha^{-1}	1.48	1.44 a	38.5 a	38.12ab	0.68 b	0.74 a	32.18	44.35	21.76	22.11
T2: Cattle Manure @ 5 t ha^{-1}	1.42	1.37 c	37.5ab	37.32 b	0.61 c	0.72 a	30.59	44.33	21.56	21.91
T3: Cattle Manure + Compost each @ 2.5 t ha^{-1}	1.40	1.38 bc	36.5 ab	40.66 a	0.75 a	0.77 a	30.04	41.75	21.37	21.74
T4: NPK @ 150:120: 90	1.49	1.46 a	35.75 b	38.47 ab	0.43 d	0.44 b	29.96	40.22	20.13	20.47
T5: Control (No amendment)	1.45	1.44 a	36.5 ab	39.95 ab	0.32 e	0.32 b	30.48	41.31	20.99	21.35
LSD	NS	0.0584	2.5394	3.0363	0.0445	0.1937	NS	NS	NS	NS

Means followed by similar letter in a column are non – significant at 5% level of significance

Table 6: *Growth and yield contributing parameters of wheat as affected by the organic and inorganic amendments*

Treatments	Plant Height (cm)		Days to heading		No. of Tillers Plant^{-1}		No. of Grain spike^{-1}	
	2014 – 15	2015 – 16	2014 – 15	2015 – 16	2014 – 15	2015 –16	2014 –15	2015 – 16
T1: Compost @ 5 t ha^{-1}	75.0 b	74.75 bc	74.75 bc	117.50 b	4.25 b	6.50	36.75 ab	32.25 ab
T2: Cattle Manure @ 5 t ha^{-1}	79.0 b	87 ab	87 ab	116.50 bc	3.75 b	4.50	37.0ab	26.00 b
T3: Cattle Manure + Compost each @ 2.5 t ha^{-1}	75.25 b	86.5 ab	86.5 ab	119.75 a	5.0 b	4.00	34.0ab	28.50 b
T4: NPK @ 150:120: 90	91.25 a	88.5 a	88.5 a	120.25 a	7.25 a	6.75	44.5 a	37.75 a
T5: Control (No amendment)	71.25 b	83.75 c	83.75 c	114.75 c	3.5 b	4.50	33 b	26.0 b
LSD	8.388	2.67	2.67	2.20	2.10	NS	11.33	7.45

Means followed by similar letter in a column are non – significant at 5% level of significance.

Table 7: *Yield parameters of wheat as affected by the organic and inorganic amendments*

Treatments	1000 grain weight (g)		Biological Yield (kg ha^{-1})		Grain yield (kg ha^{-1})		Straw yield (kg ha^{-1}		Harvest Index (%)	
	2014 – 15	2015 – 16	2014 – 15	2015 – 16	2014 – 15	2015 – 16	2014 – 15	2015 – 16	2014 – 15	2015 – 16
T1: Compost @ 5 t ha^{-1}	34.5 b	34.02	5181 b	4085 b	1413.25 b	1501 b	3767.75 b	2511.5 bc	27.27 b	38.72 ab
T2: Cattle Manure @ 5 t ha^{-1}	35 b	34.42	4166.7 d	3040 c	1103.25 d	1215.8 bc	3063.5 d	1836.5 bc	26.47 d	40.05 a
T3: Cattle Manure + Compost each @ 2.5 t ha^{-1}	36.5 a	32.60	4851.7 c	2785 c	1301.5 c	1028.3 bc	3550.2c	2806.8b	26.82 c	36.52 bc
T4: NPK @ 150:120: 90	34.5 b	32.60	11656.7 a	12435a	3887.5 a	3969.8a	7769.2a	8465.3 a	33.35 a	31.70 d
T5: Control (No amendment)	35 b	35.30	3520.5 e	2325 c	885.5 e	870.3 c	2635 e	1170.8 c	25.15 e	37.41b
LSD	1.01	NS	82.37	875.73	25.51	520.72	62.51	1443.8	0.23	2.60

Means followed by similar letter in a column are non – significant at 5% level of significance.

Number of grains spike^{-1}: In the current study the organic amendments showed significant effect on number of grains spike-1 of wheat grown during the two consecutive years (Table 6). Number of grains spike-1were found greater (44.5) in the plots receiving inorganic fertilizer (NPK) over the control (33 grains per spike). The commercial fertilizer gave the similar higher number of grain per spike during the second year; it was followed by the organic amendment of compost applied @ 5 t ha-1. Rehman et al. 2008 found greater number of grains spike-1with the increment of NPK fertilizer over the control. Iqtidar et al. (2006) also reported similar results.

Number of tillers plant^{-1}: Number of tillers plant-1in the current experiment showed significant response to inorganic and organic amendments during first experimental year with significantly highest number of tillers in the inorganic fertilizer over the rest of the treatments (Table 6). While in the second year it was non – significantly changed. Hossaen et al. (2011) revealed that application of inorganic fertilizer increased number of tillers hill-1 of rice over the control. Similarly, Chander and Pandey (1996) reported that number of effective tillers increased significantly with the increase application of nitrogen, while the in-effective tillers per hill varied significantly with the application of different organic manures.

Yield parameters of wheat

Thousand grain weight:

Thousand grain weight in the study showed significantly effect of cattle manure and compost during the initial year, while it was non- significantly changed during the second year of study (Table 7). Maximum (36.5 g) in the plots that were receiving cattle manure + compost each @ 2.5 t ha-1, minimum weight (34.5 g) was received from both of the treatments i.e. control and NPK applied @ 150:120:90 kg ha-1during first experimental year. Rehman et al. (2008) recorded highest thousand grain weight by the application of FYM. Similarly, Hossain et al. (2002) and Brown and Petrie (2006) reported increase in thousand grains weight by the application of FYM and inorganic fertilizers.

Total dry matter yield (TDM): The TDM yield of wheat was significantly affected during the two experimental years by the application of treatments (Table 7). In the initial year TDM was found highest (11656.75 kg ha-1) in the plots receiving synthetic fertilizer (NPK). It was lowest in control, with the value of 3520.5 kg ha-1. In the succeeding year of the experiment almost similar trend was found, with significantly maximum biomass of 12435 kg ha-1 was found in the treatment, where NPK was added @ 150:120:90 kg ha-1. It was followed by the treatments receiving compost @ 5 t ha-1, cattle manure@ 5 t ha-1, and cattle manure + compost each @ 2.5 t ha-1 respectively. The least quantity of biomass was found in control, with the value of 2325 kg ha-1. These results are in accordance with the results of Badruddin et al. (1999), Alvarez et al. (2004) and Shaheen et al. (2014) who reported significant effect of NPK on the total biomass over the control.

Grain yield: In the current study commercial fertilizer, organic manures and compost showed significant influence on grain yield of wheat during the two experimental years (Table 7). Grain yield was found maximum 3887.5 kg ha-1 in plots receiving the stated dose of NPK. It was followed by the treatment of compost @ 5 t ha-1, cattle manure + compost each @ 2.5t ha-1 and cattle manure @ 5 t ha-1respectively. The least quantity of grains was recorded in the plots receiving no amendments. In the next year similar trend was observed, with significantly maximum yield of 3969.8 kg ha-1 was received from the plots where standard dose of NPK was applied. The least value of grain yield was found in control, with the value of 974.3 kilograms ha-1. Sohu et al. (2015) reported greater grain yield of gram applied with the inorganic fertilizer over the sole poultry manure and farmyard manure.

Mbah and Onweremadu (2009) reported higher yield of maize by using the mineral fertilizers over poultry dropping, burnt and unburnt rice husk. The highest grain yield may be attributed to the readily available nutrients in the mineral fertilizers, while the slower decomposition of nutrients from the organic sources. Similar finding have been reported by Munecheru-muna et al. (2007).

Straw yield kg ha^{-1}: Straw yield (kg ha-1) of wheat received after harvesting showed significant difference amongst the treatments in both of the study years (Table 7). In the initial year, straw yield was 7769.25 kg ha-1in the plots where inorganic fertilizers were applied. Also the treatments receiving compost @ 5 t ha-1, cattle manure + compost each @ 2.5 t ha-1and cattle manure@ 5 t ha-1 gave significantly higher

straw yield over the control. In the subsequent year of experiment similar trend was found, with significantly maximum straw yield attained 3969.8 kg ha-1 through synthetic fertilizer application. Shahzadi et al. (2014) reported greater straw yield of wheat in the treatment of mineral NPK fertilizers over the sole FYM, filter cakes, solid municipal wastes treatments.

Harvest Index (%): Harvest Index (HI) is an important parameter describing the amount of grains received from total dry matter yield of a crop. In the current study the inorganic amendments showed significant effect on harvest index (%) of wheat during the first experimental year, while the cattle manure gave higher value of HI during the second year of the experiment (Table 7). Comparing the results of two years, harvest index showed that in year 2014–15 treatment receiving inorganic fertilizer gave the highest 33.35% over the rest of the treatments. In the next year (2015-16) the result were completely inverse with the highest harvest index of 40.05 % in the treatment receiving cattle manure @ 5t ha-1, which was statistically at par with plots receiving compost @ 5 t ha-1. The least quantity was recorded in the plots receiving inorganic fertilizer. This might have been attributed to the nitrogen fertilizers which increased the total matter yield. Anwar et al. (2015) reported the highest HI by the application of manures along with inorganic fertilizers. Hammad et al. (2011) reported higher harvest index by the application of green manures, poultry litter and sewage sludge over the recommended NPK fertilizer.

Conclusions

The use of mineral fertilizer showed significantly higher water use efficiency; TDM, grain and straw yield as compared with the organic manures, but the organic fertilizer were effective in improving the soil properties, which ultimately will result in enhancing the response by the crops.

Author's Contribution

AS and MM conceived the idea. QK entred the data in SPSS and analysised it. AS and QK wrote the manuscript. QK, MM and MJK provided technical input at every step. MJK did overall management of the article.

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