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RESEARCH ARTICLE

Impacts of Blended NPSB Fertilizers on Growth and Phenology of Orange Fleshed Sweet Potato (*Ipomoea batatas* [L.] Lam.) at Central Ethiopia

Ibrahim Mehdi[1], Hayub Taju[2], Adeselem Mebratu[3]

[1]Department of Animal and Range Sciences, College of Agriculture and Natural Resources, Jigjiga University, Jigjiga, Ethiopia, [2]Department of Horticulture, Office of Agriculture, Qebena Special Woreda, Central Ethiopia, [3]Department of Horticulture, College of Agriculture, Wolkite University, Wolkite, Ethiopia

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ABSTRACT

Even though, sweet potato (*Ipomoea batatas* [L] Lam) is one of the most economically important crops, its production and productivity are very low in Ethiopia. Several factors as lack of know – how about the types, levels of fertilizers supply, and improved potato variety are among few. As a result, such an experiment, which was conducted on the field at Qebena special woreda, Reka-boka kebele for evaluating the effects of four different rates of NPSB fertilizers (0, 75, 150, and 225 kg/ha) on growth and phenology of three orange-fleshed sweet potato (OFSP) varieties (Kebode, Alamora, and Dilla). The experiment was arranged in a 3 × 4 factorial randomized complete block design with three replications. The study revealed that the rates of blended fertilizers NPSB highly significantly influenced the vine number, inter-node length, shoot fresh weight (SFW), shoot dry weight (SDW), and total tuber number/plant. However, the vine number, inter-node length, number of leaves/plant, SFW, and SDW resulted significantly in the highest difference due to the effect of both variety and fertilizer ($P < 0.01$). Statistically, the highest vine length was obtained from the Dilla variety at 225 kg/ha (282.22). Alamora with 150 kg/ha rates of NPSB fertilizer resulted significantly higher difference in vine number (12.22). Dilla variety at 225 and 150 kg/ha resulted in the highest number of leaves per plant (659.72 and 632.22), respectively. The Dilla variety at 225 kg/ha, which resulted in significantly higher differences in both shot fresh and dry weights (1526.10 and 6466.67 kg/ha). Utilization of such selected OFSP variety with different levels of NPSB fertilizes for further studies needed at different parts of the country to improve. For the best variety and fertilizer responses.

Key words: Biomass, blended NPSB rate, orange-fleshed sweet potato, tuber yield

INTRODUCTION

Sweet potato (*Ipomoea batatas* [L.] Lam) is a dicotyledonous plant belonging to the family *Convolvulaceae*.[1] It is mainly grown for human food and animal feed. It produces storage roots which are rich in carbohydrates, vitamins such as A, B complex, C, and E, and minerals such as potassium, calcium, and iron.[2] The Central American countries are considered the center of sweet potato origin, while an important food security crop cultivated in over 100 developing countries. However, it is extensively cultivated with a divergent agro-climatic condition and domesticated more than 5000 years ago,[3] as a root crop that provides food to a large segment of the world population.

Now, it is widely grown throughout the tropics and temperate regions of the world between latitudes of 400 North and South of the equator and 2300 m above sea level. Globally, sweet potato is the

Address for correspondence:
Ibrahim Mehdi
E-mail: ibromehdi2013@gmail.com

seventh most important food crop after wheat, rice, maize, potato, barley, and cassava.[4] In Asia, sweet potato is primarily used for human consumption and animal feed. It is second most important root crop after cassava in Africa, and its production is concentrated in the East African and the African Great Lake regional countries.[5,6] Ethiopia is one of the largest sweet potato-producing countries, which is widely grown in the southern, southwestern, and eastern parts by small-scale farmers with limited land, labor, and capital.[7,8]

In Ethiopia, sweet potato is cultivated as the most important root crop mostly for human consumption, which ranks the third most important root crop next to enset and potato in the country. It is the most important source of carbohydrates for smallholder farmers in Ethiopia.[9] It is one of the major horticultural crops used as a source of food and income to the poor farmers and a major subsistence crop in the drought periods.[10,11] However, the productivity of the crop remained low at the national level (8 ton/ha) for a long time.[12] The major causes of the low yields are the use of poor agronomic practices and extension systems, lack of information on the appropriate rates of fertilizer recommendations, low soil fertility, the shortage of improved varieties, and shortage of planting materials.[13] Sweet potato production is also constrained by biotic (diseases, insects, pests, and weeds), and abiotic factors (drought, heat, and low soil fertility).[14]

Several experiments were conducted to determine the responses of the sweet potatoes to organic and inorganic fertilizers using different rates. However, yield response varies from variety to variety, levels of fertilizers, and from place to place. Even though a number of experiments had been conducted on the evaluation of different orange-fleshed sweet potatoes (OFSP) varieties in different parts of Ethiopia, mainly on yield improvement less emphasis was given to the effects of blended NPSB fertilizer rate in relation to different varieties of OFSP. To date, little information was exploited on the effects of inorganic fertilizers, and the NPSB on the yield and quality of OFSP in the study area. Thus, the objective of the study was to understand the effects of blended fertilizers NPSB on different varieties of OFSP growth attributes and phenology.

MATERIALS AND METHODS

Descriptions of the Study Area

The experiment was conducted at the Farmer's Training Center at Reka-boka Kebele, Qebena Special Woreda, Central Regional State of Ethiopia, during the main rainy season. It was located 158 km from Addis Ababa, and 5 km from Wolkite town in South West direction at a latitude of 8°0'N and longitude of 37°49'E with an elevation of 2000 m.a.s.l. The average annual rainfall ranges between 1500 and 1800 mm with mean annual maximum and minimum temperatures of 20°C and 12.6°C.

Experimental Materials

Three nationally released potato varieties; which were brought from the Hawasa research center: Kabode, Dilla, and Alamura were used. The varieties were selected based on their wider adaptability, yield potential, and relative tolerance to disease compared to the local varieties. They have had more/less similar ecological requirements, growing periods, and the detailed description of the varieties given in Table 1.

Experimental Design and Treatments

The experiment consisted of four levels of blended NPSB fertilizers rate: (0, 75, 150, and 225 kg/ha), and three OFSP varieties (Kabode, Dilla, and Alamura) in a complete factorial arrangement. A total of 12 (3 × 4) factorial treatment combinations were laid out in a randomized complete block design, with three replications. The distance between blocks and plots was 1 m and 50 cm, respectively. The gross plot size for each treatment was 1.8 m × 2.4 m (4.32 m^2). The spacing between rows and plants was 60 cm and 30 cm, respectively, and each plot accommodated 24 plants.

There was a lack of baseline information about levels of NPSB fertilizer to be applied. Since the experiment was new for study area. Hence, NPSB rates were determined on the basis of previously recommended N_2 and P_2O_5 at the rate of 150 and 150 kg/ha Urea and DAP, respectively. To determine NPSB rates, 50% of P_2O_5 (DAP) available at blanket

Table 1: The description of improved potato varieties used for the study

varieties	year of release	rf (mm)	altitude	maturity time	yield tha^{-1}	breeder/maintainer
kabode	2005	750–1000	1200–2200	150	27.0	harc
alamura	2006	750–1000	1600–2800	110–120	29.2	harc/eiar
dilla	2006	750–1000	1600–2800	150	21.0	harc/eiar

source: ministry of agriculture (moa, 2012)

(150 kg/ha) were converted in terms of NPSB. NPSB fertilizer was used as a source of P_2O_5, S, and B while urea was used to compensate N_2 which was not covered by NPSB in treatment.

Experimental Site Preparation and Soil Sampling

The land was prepared in accordance with a standard practice used. The experimental site was plowed using a tractor, then after using oxen 2 times. Before planting, soil samples were randomly collected using an auger in a zigzag pattern at 30 cm depth. The soil samples from 10 spots across the site were collected, composited, and packed to determine the soil physicochemical properties such as texture, pH, cation exchange capacity (CEC) (Cmol $[^{+}]$ kg^{-1}), organic carbon(%), total N_2 (%), available phosphorus (mg/kg [ppm]) to Wolkite soil laboratory before planting.

In accordance with the specification, the layout was prepared and each treatment was assigned at random to experimental plots within each block independently. Uniform and recommended sizes of sweet potato vine cuttings were planted in a well-prepared ridge at the recommended spacing of 0.3 m between plants and 0.60 m between rows.

Based on the treatments, NPSB fertilizers were applied 8 days after the time of planting. The total quantity of N_2 in NPSB was subtracted and the remaining N_2 from the blanket recommendation (100 kg/ha urea) was applied in splits, the first half after a week, and the rest was applied in two splits at 25 and 50 days after planting. All the recommended cultural practices including weeding, pest, and disease control were done uniformly for all experimental plots.

Data Collected

After proper recording, all the data related to crop phenology, and growth attributes due to blended fertilizer applications and varieties were taken from three plants from a net plot at random. The detailed growth parameters for different data collection are given below:

- Days to bud sprouting (DBSP): This was recorded when 50% of the vine cuttings sprouted
- Number of vines/plants: The average number of branches/stems emerging from the main stem. This was counted at the time of 80 days after planting
- Number of leaves/plant: The average number of leaves from selected plants was recorded at the time of 80 days after planting
- Vine length (VL): The height of the plant from the base to the terminal tip of the plant at which the maximum height was attained and recorded in (cm)
- Inter-nodes length: The average length of inter-nodes from the point where the first node started from the base to the tip of the vine was recorded for growth rate determination at 70 days after planting (cm)
- Days to maturity (DTM): The number of days taken from planting to harvesting was determined by cutting the sampled tubers into two pieces and after a few hours the matured tuber remained as it is, whereas immature ones became darkened
- Shoot fresh weight (SFW): It includes a fresh mass of vines and leaves. It was recorded by cutting the plants at the soil surface at the time of 65 days after harvesting and weighed in (g)
- Shoot dry weight (SDW): This was obtained and recorded by drying the above-ground biomass of vine and leaves using balance and recorded in grams.

Data Analysis

The collected data of all parameters were subjected to analysis of variance using the Statistical Analysis

Software version 9.3.[15] The treatment mean comparisons were done using the least significance difference test at 5% level of significance. The correlation analysis among selected parameters was done using Pearson's simple correlation coefficient.

RESULTS AND DISCUSSIONS

SOIL Physicochemical Properties

The physicochemical properties of the soil before planting are shown below under [Table 2]. Accordingly, the result showed that the soil textural class was clay. The pH was neutral. The CEC of the soil was (42 mg/100 g) which was a medium. The soil had a low total N_2 concentration (1.287%) and moderate (31.21 ppm) available phosphorus level. Since, the root of sweet potato root is short and small, which does not easily utilize less readily available phosphorus, an extensive amount of readily available phosphorus is required. Thus, the site was appropriate for sweet potatoes.

Table 2: Pre-planting soil physicochemical properties of the experimental site

Physio-chemical properties	Result	Status	References
Clay (%)	46		
Silt (%)	28		
Sand (%)	26		
Textural class		Clay	USDA, 1987
p^H (1:2.5H_2O)	7.1	Neutral	Tekalign (1991)
OC (%)	14.93	Low	Tekalign (1991)
OM (%)	2.48	Medium	Tekalign (1991)
Total N_2 (%)	1.29	Low	Murphy (1968)
Available *P* (ppm)	31.21	Medium	Cottenie (1980)
CEC (mg/100 g)	42	Medium	Murphy (1968)

CEC: Cation exchange capacity

Blended NPSB Fertilizer Effects on Phenology

DBSP

Days to bud sprout were highly significantly ($P < 0.01$) affected by the main effects and non-significant by the interaction of blended NPSB fertilizer rates and varieties. The highest DBSP (12.00) was recorded on Kebode, with no NPSB fertilizers application, while the delayed DBSP (6.00) was recorded on Dilla that received 150 kg/ha NPSB fertilizers, however, it was not significantly different from the Alamora variety treated with 225 kg/ha (6.33) of NPSB fertilizer [Table 3].

The differences in DBSP for varieties under the application of different rates of NPSB might be due to the differences in the inherent genetic potential of varieties in response to nutrients. This result was in line with,[16] who reported that Dimtu at 0 kg/ha fertilizer rates resulted in significantly the highest DBSP (14.0)[17] and also reported that the time taken for bud sprouting was significantly shorter, 1.25, and 1.78 days as N_2 applications increased from 0 to 90 kg/ha and phosphorus applications increased from 0 to 75 kg/ha, respectively. Similarly,[18] reported that the N_2 and P_2O_5 increased from 45 to 90 kg/ha and 25 to 75 kg/ha, respectively, Bud sprouting was uniform and early.

Table 3: Effects of NPSB fertilizer on days to bud sprout and maturity of OFSP varieties

Varieties	NPSB kg/ha	Days to bud sprouting	Days to maturity
Dilla	0	8.67[cde]	143.67[c]
	75	7.67[ef]	151.33[b]
	150	6.00[g]	152.33[b]
	225	6.33[g]	159.33[a]
Kebode	0	12[a]	124.33[f]
	75	10.67[b]	127.00[ef]
	150	9.33[c]	131.00[de]
	225	9.00[cd]	132.33[d]
Alamora	0	8.67[cde]	146.00[c]
	75	8.00[de]	152.00[b]
	150	6.67[fg]	158.67[a]
	225	6.33[g]	162.33[a]
Mean		8.28	145.03
CV (%)		9.26	1.71

OFSP: Orange fleshed sweet potato

Days to physiological maturity

Days to physiological maturity were highly significantly ($P < 0.01$) affected by the main effect of blended NPSB fertilizer rates and variety, and their interaction ($P < 0.05$). The highest days to physiological maturity (162.33) were obtained from the variety Alamora with 225 kg/ha blended NPSB fertilizer, while it was not significantly different from Dilla treated at 225 kg/ha (159.33) and Alamora with 150 kg/ha NPSB fertilizer rate (158.67). However, at the earliest days, the physiological maturity (124.33) was recorded from the Kebode variety control treatment [Table 3].

The differences in days to physiological maturity of varieties might be attributed to the genetic difference of varieties in response to nutrients. The prolonged DTM might be attributed to the prolonged canopy growth in response to higher NPSB doses to maintain physiological activity for extended periods to continue photosynthesis. The use of inorganic fertilizer leads to increased leaf area that increases the amount of sun radiation intercepted by increasing days to flowering, physiological maturity, plant height, and dry matter accumulation.

Therefore, the presence of N_2 in excess promotes the development of the aboveground, and the protein synthesis and formation of new tissues were stimulated, which resulted in vigorous vegetative growth and increased days of physiological maturity,[16] reported that the highest days to physiological maturity (143.1) for the variety Tola with 200 kg/ha.[19] also reported that increasing the amount of N_2 applied for prolonged days to physiological maturity on sweet potatoes.

Blended NPSB Fertilizer on Growth Parameters

Vine number, VL, and Inter-node length

The result revealed that the interaction of variety and NPSB blended fertilizer rate significantly influenced the vine number, internode length ($P < 0.01$), and VL ($P < 0.05$) [Table 6]. Sweet potato variety Alamora, which received 150 kg/ha recorded significantly the highest vine number (12.22), followed by Alamora and Dilla which received 225 kg/ha NPSB fertilizer, which were not statically differ from each other [Table 4]. The lowest vine number (5.44) was recorded in Kebode without NPSB fertilizers. The reason might be due to the most of energy synthesized was used to fill the storage roots rather than to maintain vegetative parts. Most of the photosynthates in the vegetative parts are translocated to the roots for bulking. This was in line with the finding of[20] who reported that the interaction of variety and NPSB blended fertilizer rate significantly influenced vine number.

The variety Alamora, which received 225 kg/ha NPSB fertilizer significantly the highest VL (282.22 cm), significantly differs from all other treatments. The kebode variety, that received 0 kg/ha NPSB resulted the least VL (79.56 cm). However, it was not significantly different from Kebode at all fertilizer rates [Table 4]. Even though the VL was least and non-significant by Kebode at all NPSB, it increased in length from 0 to 225 kg/ha [Table 3]. The differences in VL for varieties under different rates of NPSB might be due to the differences in the inherent genetic potential of varieties. This was in line with the finding of,[20] who reported that the interaction of variety and NPSB blended fertilizer rate significantly influenced the VL.

Table 4: Effect of OFSP varieties and NPSB on vine number, length, and internode length

Variety	npsb kg/ha	vine numbers	vine length (cm)	internode length (cm)
Dilla	0	7.44^{fe}	236.67^{ab}	18.45^{e}
	75	8.22^{d}	240.56^{ab}	23.83^{bc}
	150	9.45^{c}	204.44^{b}	27.11^{a}
	225	11.44^{b}	282.22^{a}	26.99a
Kebode	0	5.44^{g}	79.56^{c}	12.46^{f}
	75	7.33f	99.55^{c}	23.25^{bc}
	150	8.78^{cd}	109.45^{c}	21.89^{cd}
	225	7.44^{de}	120.56^{c}	24.11^{bc}
Alamora	0	8.22^{d}	231.98^{ab}	26.89a
	75	9.22^{c}	252.22^{ab}	20.22^{de}
	150	12.22^{a}	238.67^{ab}	24.75^{ab}
	225	11.44^{b}	265.56^{ab}	27.22^{a}
Mean		8.94	195.29	23.09
CV (%)		4.97	20.80	6.43

OFSP: Orange fleshed sweet potato

Similarly,[21] showed that the VL increased with applied phosphorus up to the rate of 46 kg/ha P_2O_5, while further increase of phosphorus reduced the VL.[16] Reported that the highest VL for the Tola variety that received 200 kg/ha NPSB scored 177.2 cm. Moreover,[22] reported that the VL was decreased when the rate beyond 60 kg/ha. According to[23] the sweet potato benefited little from phosphorus to increase its canopy.

Number of leaves per plant, shoot fresh, and dry weights

The influence of varieties and NPSB fertilizer were highly significantly different on shoot fresh- and dry-weights, and leaf/plant numbers ($P < 0.01$) [Table 7]. The Dilla variety at 150 kg/ha NPSB resulted in the highest leaf number (659.72), while, it was significantly not different from Dilla (631.22) at 225 kg/ha and Alamora at 150 kg/ha NPSB fertilizer application (608.94) [Table 5]. Therefore, the finding was in line with that of[20] the interaction effects of varieties with NPSB blended fertilizer resulted in a highly significant difference in leaf number. Moreover,[24] reported that the highest number of leaves per plant by Okumkom grown on 30–45–45 kg/ha NPK which was significantly different from other amended and control plots. Contrarily,[22] reported that the leaf number did not show any significant differences at the highest 60 P_2O_5 kg/ha or 26.4 P kg/ha.

Table 5: Effect of NPSB on the number of leaf/plant, shoot fresh, and dry weights of OFSP varieties

Variety	NPSB kgha^{-1}	Number of leaves per plant	Shoot fresh weight	Shoot dry weight
Dilla	0	496.11^{d}	9427.80^{d}	3480.00^{f}
	75	571.22^{bc}	10394.40^{c}	4401.22^{c}
	150	631.22^{a}	14338.90^{b}	5472.22^{b}
	225	659.72^{a}	1526.10^{a}	6466.67^{a}
Kebode	0	169.11^{g}	2972.20^{g}	1338.89^{j}
	75	229.83^{f}	3623.30^{g}	1402.78^{j}
	150	264.03^{f}	6920.00^{f}	2438.89^{h}
	225	271.63^{f}	7138.90^{f}	2938.89^{g}
Alamora	0	377.52^{e}	7966.70^{e}	2161.11^{i}
	75	544.76^{d}	8061.10^{e}	2505.56^{h}
	150	567.50^{bc}	9594.40^{cd}	3911.11^{e}
	225	608.94^{ab}	9833.30^{cd}	4166.67^{d}
Mean		449.30	6794.35	3390.09
CV (%)		6.92	5.48	2.37

OFSP: Orange fleshed sweet potato

Significantly the highest SFW (15.26 tha^{-1}) was recorded from the Dilla variety with 225 kg/ha, followed by 150 kg/ha (14.34 tha^{-1}), and 75 kg/ha (10.4 tha^{-1}) NPSB. The lowest SFW was recorded from Kebode at a nill rate, but not significantly different from Kebode at 75 kg/ha (57.24 tha^{-1}) [Table 5]. This was in line with[20] stating that the effects of varieties and NPSB rates highly significantly influenced the aboveground biomass fresh weight.[18] Reported that an increase from 0 to 25 kg/ha phosphorus increased biomass significantly. However, increase from 50 to 75 kg/ha, there was a significant decrease and the highest biomass was recorded at 25 kg/ha on ridge and flat. SDW was significantly highest and recorded by Dilla with NPSB 225 kg/ha (64.67 tha^{-1}). Moreover, the least was recorded by Kebode without NPSB, not significantly different from Kebode, which received 75 kg/ha. It was in agreement with the findings of[16] who reported that SDW was highly significantly affected by the variety and interaction of NPSB and variety[18] reported the highest SDW

Table 6: Mean squares for ANOVA of vine number, vine length, and internode length

Source of variation	DF	Vine number	Vine length (cm)	Internode length (cm)
Replication	2	0.03^{ns}	318.79^{ns}	0.39^{ns}
Fertilizer (NPSB)	3	67.41**	3683.5*	79.13***
Variety (VAR)	2	49.82**	77861.09***	65.59***
NPSB x VAR	6	10.12**	867.24^{ns}	44.27**
Error	22	4.35	1650.55	48.0
CV (%)		4.97	20.80	6.43
Mean		197.68	195.28	23.09

*Significant at the $P<0.05$ probability level; **Significant at $P<0.01$ probability level; ***Significant at the $P<0.001$ probability level. Ns: Non-significant, VN: Vine number, VL: Vine length, IL: Internode length, ANOVA: Analysis of variance

Table 7: Mean squares for ANOVA for Number of leaf/plant, shoot fresh and dry weight

Source of variation	DF	Number of leaves per plant	Shoot fresh weight	Shoot dry weight
Rep	2	615.53*	729465.9*	3973.09
Fertilizer (NPSB)	3	47777.99***	36310641.9***	9314107.07
Variety (VAR)	2	431173.53***	155215725.2***	26045172.09
NPSB x VAR	6	2744.30*	2783660.8***	293027.92
Error	22	966.14	232686.6	6469.40
CV (%)		6.92	5.48	2.37
Mean		449.30	8797.35	3390.09

*Significant at the $P<0.05$ probability level; **Significant at $P<0.01$ probability level; ***Significant at the $P<0.001$ probability level. Ns: Non-significant, NLPP: Number leaf per plant, SFW: Shoot fresh weight, SDW: Shoot dry weight, ANOVA: Analysis of variance

(207 g) at 90 kg/ha and 25 kg/ha of N_2 and P_2O_5, respectively.[25] Furthermore, stated that SDW was increased as the proportion of FM: P decreased.[19] Furthermore, stated that the application of 92 kg/ha N_2 and 23 kg/Pha increased aboveground dry biomass production in sweet potatoes.

SUMMARY AND CONCLUSION

Sweet potato (*Ipomoea batatas* [L.] Lam) is an economically important food security crop in Ethiopia. OFSP are nutritious and widely cultivated root crops known for their high β-carotene content, which has proven a cost-effective strategy for providing Vitamin A. However, its average yield in the country is about 8 ton/ha which is very low as compared to the world's average production (14.8 ton/ha). The major cause of the low yield is the use of poor agronomic practices, scarcity of information on appropriate types and rates of fertilizers, and shortage of improved varieties having high nutritional and dry matter.

Growth parameters are the main important yield-determining factors in sweet potato and they are highly influenced by soil fertility and amendments. This finding revealed that mean vine number, internode length, shoot fresh, dry weight, and total tuber number/plant were highly significant ($P < 0.01$) at the NPSB fertilizer rate. The Dilla variety, which received 225 kg/ha NPSB resulted significantly higher difference in VL. While the least VL at 150 kg/ha (96.6 cm) was Kebode variety. The number of leaves/plants of the Dilla variety resulted significantly highest at 225 kg/ha (659.72) and 150 kg/ha (631.22) NPSB rates. The SFW resulted highest in Dilla at 225 kg/ha (1526.10 kg/ha) NPSB rate. Root fresh weight was significantly higher in Kebode at 150 kg/ha (22762 kg) than the Kebode variety at 225 kg/ha. However, root dry weight was highest in Kebode at 150 kg/ha (20524.7 kg), 225 kg/ha NPSB (17978.4 kg), respectively, and the highest total tuber number was Kebode at 150 kg/ha (20.52 t.ha).

RECOMMENDATION

- Further study will be recommended on various OFSP varieties to know the effects of rates of NPSB fertilizer at various localities of the country.

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CONFLICTS OF INTEREST

- The authors declare there are no conflicts of interest regarding the publication.

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