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EFFECT OF FOLIAR APPLICATION OF IRON AND ZINC ON MORPHO-PHYSIOLOGICAL PARAMETERS AND YIELD IN SAFFLOWER (*Carthamus tinctorius* L.)

Avinash P. Kesarkar[1], P. V. Shende[2], Vinita S. Karad[3], P. R. Manapure[4], R. D. Deotale[5] and S. D. Tupkar[6]

ABSTRACT

An investigation entitled "Effect of foliar application of iron and zinc on morpho-physiological parameters and yield in safflower (*Carthamus tinctorius* L.)" was carried out at farm of Agril. Botany, College of Agriculture, Nagpur, during *rabi* 2020-2021. The experiment was arranged in randomized block design and replicated thrice consisting nine treatments of ferrous sulphate and zinc sulphate @ 0.5% and 1% when applied individually and in their combinations. The foliar spray at 30 and 50 DAS showed significant increase in all the growth parameters i.e. plant height, number of primary branches, plant^{-1} number of secondary branches, number of leaves plant^{-1}, leaf area, leaf area index, dry matter production, days to 50 per cent flowering, days to maturity, RGR, NAR, CGR and seed yield plot^{-1}. Application of $FeSO_4$ 0.5% + $ZnSO_4$ 1.0% gave significantly higher results in all parameters under study when compared with control and rest of the treatments.

(Key words : Safflower, ferrous sulphate, zinc sulphate, morpho-physiological parameters, yield)

INTRODUCTION

Safflower (*Carthamus tinctorius* L.) is a member of Compositae or Asteraceae family cultivated mainly for its seed, which is used as edible oil and as bird-seed. Safflower is a highly branched, herbaceous, thistle-like annual or winter annual, usually with many long sharp spines on the leaves. Plants are 30-150 cm tall with globular flower heads capitula and commonly brilliant yellow, orange or red flowers. Achenes are smooth, four-sided and generally lack pappus. The plant has strong taproot which enables it to thrive in dry climates.

India ranks second in case of production of safflower after Kazakhstan. Other safflower growing countries are USA, Mexico, Argentina, Turkey etc. The largest safflower producing states in India are Maharashtra, Karnataka and parts of Andhra Pradesh, Madhya Pradesh, Orissa, Bihar, etc. In India Maharashtra ranks first in terms of area and production.

Iron is an essential nutrient that plays a critical role in life sustaining processes. Due to its ability to gain and lose electrons, iron works as a cofactor for enzymes involved in a wide variety of oxidation-reduction reactions (i.e. photosynthesis, respiration, hormone synthesis, DNA synthesis, etc.). This function makes iron an essential nutrient, and its deficiency causes iron chlorosis. Iron toxicity in plants is indicated by bronzing characteristics, which have been observed in plants grown in greater than 100 mM iron solutions. Higher iron uptake by plants reduces protein synthesis in leaves. (Rout and Sahoo, 2015).

Zinc sulphate is most commonly used source of zinc. The Zn plays very important role in plant metabolism by influencing the activities of hydrogenase and carbonic anhydrase, stabilization of ribosomal fractions and synthesis of cytochrome. Plant enzymes activated by Zn are involved in carbohydrate metabolism, maintenance of the integrity of cellular membranes, protein synthesis, and regulation of auxin synthesis and pollen formation. Its deficiency results in the development of abnormalities in plants which become visible as deficiency symptoms such as stunted growth, chlorosis and smaller leaves, spikelet sterility (Hafeez *et al.* 2013). Hence, present investigation was carried out to study the influence of Fe and Zn on morpho-physiological parameters and yield in safflower.

MATERIALAS AND METHODS

Present investigation was under taken during *rabi* 2020-21 on the farm of Agriculture Botany Section, College of Agriculture, Nagpur. The investigation was laid out in randomized block design with 3 replications. There were

1, 3 and 6. P.G. Students, Agril. Botany Section, College of Agriculture, Nagpur
2. Asso.Professor, Agril. Botany Section, College of Agriculture, Nagpur
4. Professor, Agril. Botany Section, College of Agriculture, Nagpur
5. Ex- Professor,Agril. Botany section, College of Agriculture, Nagpur

nine treatments *viz*., T_1 (control), T_2 ($FeSO_4$ 0.5%), T_3 ($FeSO_4$ 1.0%), T_4 ($ZnSO_4$ 0.5%), T_5 ($ZnSO_4$ 1.0%), T_6 ($FeSO_4$ 0.5% + $ZnSO_4$ 0.5%), T_7 ($FeSO_4$ 0.5% + $ZnSO_4$ 1.0%), T_8 ($FeSO_4$ 1.0% + $ZnSO_4$ 0.5%) and T_9 ($FeSO_4$ 1.0% + $ZnSO_4$ 1.0%). Two foliar spray at 30 and 50 DAS were given. PKV Pink (AKS-311) cultivar of safflower was used in the investigation. Observations on plant height, number of leaves, leaf area, leaf area index (LAI) and dry matter production were recorded at 30, 50, 70 and 90 DAS. Number of primary and secondary branches plant^{-1} recorded at harvest. Days to 50 per cent flowering and days to maturity also recorded. RGR, NAR and CGR were calculated at 30-50, 50-70 and 70-90 DAS. Seed yield plot^{-1} was recorded at the time of harvest. The observed data were analysed statistically using analysis of variance at 5% level of significance (Panse and Sukhatme, 1967).

RESULTS AND DISCUSSION

Plant height, number of primary branches plant^{-1}, number of secondary branches plant^{-1} and number of leaves plant^{-1}

The data regarding plant height at 90 DAS, number of primary branches at harvest, number of secondary branches and number of leaves at 90 DAS were found significantly higher in treatment T_7 ($FeSO_4$ 0.5% + $ZnSO_4$ 1.0%) followed by treatments T_9 ($FeSO_4$ 1.0% + $ZnSO_4$ 1.0%), T_5 ($ZnSO_4$ 1.0%), T_6 ($FeSO_4$ 0.5% + $ZnSO_4$ 0.5%) when compared T_1 (control). Application of zinc and iron through foliar sprays at 30 and 50 DAS increased plant height, number of branches and number of leaves plant^{-1}. It might be due to photosynthetic activity, chlorophyll formation, nitrogen metabolism and auxin contents in the plants.

Similar results were reported by Ravi *et al.* (2008), who studied the effect of sulphur, zinc and iron nutrition on growth, yield, nutrient uptake and quality of safflower and found that application of 30 kg S ha^{-1} + Fe (0.5%) + Zn (0.5%) as a foliar spray registered maximum plant height, number of primary and secondary branches and number of leaves plant^{-1}.

Taha *et al.* (2013) performed field experiment to evaluate growth and biological activities of safflower (*Carthamus tinctorius* L.) treated with iron and zinc foliar application. Results indicated that maximum plant height and the greatest number of primary and secondary branches of safflower plant were obtained by using the foliar application of the combination between Fe: Zn in 0.3:0.6 % ratio. Whereas, Kumara *et al.* (2020) concluded that significantly highest plant height and number of leaves plant^{-1} was recorded with the foliar application of Grade-I multi micronutrient mixture(Fe-2%, Zn-3%, Mn-1% and B-0.5%) @ 10 ml l^{-1} at 30 and 50 DAS along with soil application of $ZnSO_4$ @ 6 kg ha^{-1} at 25, 50, 75 DAS.

Leaf area plant^{-1} and leaf area index (LAI)

Leaf area depends upon the number and size of leaves. Leaf size is influenced by light, moisture and nutrients. Whereas, LAI is depends on leaf area and plant land surface area i.e. spacing.

Under the influence of foliar spray of treatment T_7 ($FeSO_4$ 0.5% + $ZnSO_4$ 1.0%) expressed significantly maximum leaf area plant^{-1} and leaf area index (LAI) followed by treatments T_9 ($FeSO_4$ 1.0% + $ZnSO_4$ 1.0%), T_5 ($ZnSO_4$ 1.0%), T_6 ($FeSO_4$ 0.5% + $ZnSO_4$ 0.5%) and T_8 ($FeSO_4$ 1.0% + $ZnSO_4$ 0.5%) when compared with treatment T_1 (control). Leaf area was significantly increased by zinc and iron possibly because it helps in greater assimilation of food material by the plant which resulted in greater meristematic activities of cells and consequently the number of leaves, length and width of leaf of plant further it leads to increase in leaf area index (LAI).

Our results are in line with that of Purushottam *et al*. (2018), who found that the leaf area index of chickpea was significantly influenced by spraying of zinc @ 0.5%. At 70 DAS leaf area Index of chickpea plants with foliar spray of 0.5% zinc sulphate was significantly higher than that of other treatments. Uikey *et al*. (2018) found the suitable micronutrient and or their combinations for foliar sprays in brinjal. Application of RDF and foliar spray of micronutrients i.e. RDF+ Borax 0.2% + $FeSO_4$ 0.5% + $ZnSO_4$ 0.5% recorded significantly more leaf area and leaf area index.

Similar results were reported by Pise *et al.* (2019), who reported that application of RDF + foliar application of $ZnSO_4$ 0.5% + $FeSO_4$ 0.5% was found more effective in enhancing leaf area, when compared with control in lathyrus. Raut *et al.* (2019) observed that foliar application of 0.5% zinc + 200 ppm ascorbic acid significantly enhanced leaf area over control in chickpea.

Dry matter plant^{-1}

At 30, 50, 70 and 90 DAS significantly higher dry matter production was observed in treatment T_7 ($FeSO_4$ 0.5% + $ZnSO_4$ 1.0%) followed by treatments T_9 ($FeSO_4$ 1.0% + $ZnSO_4$ 1.0%), T_5 ($ZnSO_4$ 1.0%) and T_6 ($FeSO_4$ 0.5% + $ZnSO_4$ 0.5%) when compared with treatment T_1 (control) and rest of the treatments. Application of ferrous sulphate and zinc sulphate significantly increased the total dry matter from 50-90 DAS. This might be due to increase in cell division and other physiological activities like carbohydrate metabolism and photosynthetic activity which leads to more production of photosynthates which resulted in increase in the total dry matter of the plant.

Our results are in line with that of Meena *et al.* (2013), who revealed that the foliar spray of 0.5% $FeSO_4$ + 0.1% citric acid treatment registered the highest dry matter accumulation at maturity of the crop. Taha *et al.* (2013) observed that dry matter production significantly increased due to foliar spray of Fe:Zn at 0.3:0.6% followed by Zn at 0.6% application in safflower.

The same results were reported by Kumara *et al.* (2020), who conducted field experiment to investigate the effect of foliar application of micronutrient mixture on growth, yield and economics of safflower (*Carthamust*

inctorius L.). The results showed that foliar application Grade-I multi micronutrient mixture (Fe-2%, Zn-3%, Mn-1% and B-0.5%) @ 10 ml l^{-1} at 30 and 50 DAS along with soil application of RDF and $ZnSO_4$ @ 6 kg ha^{-1} gave highest total dry matter production.

Days to 50 per cent flowering

The data recorded about days to 50 per cent flowering was found statistically significant. The range of days to 50 per cent flowering recorded was 86.30–96.60 days. The number of days for flower initiation was recorded highest in treatment T_7 ($FeSO_4$ 0.5% + $ZnSO_4$ 1.0%) followed by treatments T_9 ($FeSO_4$ 1.0% + $ZnSO_4$ 1.0%), T_5 ($ZnSO_4$ 1.0%), T_6 ($FeSO_4$ 0.5% + $ZnSO_4$ 0.5%) when compared with T_1 (control) and rest of the treatments.

Days to maturity

The results obtained during investigation of days to maturity significantly increased in the treatment T_7 ($FeSO_4$ 0.5% + $ZnSO_4$ 1.0%) followed by treatments T_9 ($FeSO_4$ 1.0% + $ZnSO_4$ 1.0%), T_5 ($ZnSO_4$ 1.0%), T_6 ($FeSO_4$ 0.5% + $ZnSO_4$ 0.5%) and T_8 ($FeSO_4$ 1.0% + $ZnSO_4$ 0.5%) over T_1 (control) and other treatments.

A field experiment was conducted by Janmohammad (2015) in order to investigate the influence of biological and chemical fertilizers on morphological traits, yield and yield components of safflower (*Carthamust inctorius* L.). The results showed that foliar application manganese chelate recorded highest days to maturity followed by zinc sulphate and iron chelate.

RGR (Relative Growth Rate)

The data regarding relative growth rate during 30-50, 50-70 and 70-90 DAS was found significant and the higher RGR was recorded in treatment T_7 ($FeSO_4$ 0.5% + $ZnSO_4$ 1.0%) followed by treatments T_9 ($FeSO_4$ 1.0% + $ZnSO_4$ 1.0%), T_5 ($ZnSO_4$ 1.0%) and T_6 ($FeSO_4$ 0.5% + $ZnSO_4$ 0.5%) when compared with T_1 (control) and rest of the treatments.The application of ferrous sulphate and zinc sulphate enhanced the dry matter production which results in increase in RGR

Pise *et al.* (2019) conducted triplicate field experiment laid out in randomized block design comprising of different doses of zinc (0.1%, 0.2%, 0.3%, 0.4% and 0.5%) and iron (0.1%, 0.2%, 0.3%, 0.4% and 0.5%) sprayed individually and in their combinations. Application of $ZnSO_4$ 0.5% + $FeSO_4$ 0.5% foliar recorded highest RGR followed by $ZnSO_4$ 0.5% foliar. Raut *et al.* (2019) examined the effect of ascorbic acid and zinc as a foliar application on chickpea and recorded significant increase in relative growth rate by the application of 200 ppm ascorbic acid + 0.5% $ZnSO_4$.

NAR (Net Assimilation Rate)

The net assimilation rate during 30-50, 50-70 and 70-90 DAS was found significant.The results obtained during investigation NAR was significantly enhanced by treatment T_7 ($FeSO_4$ 0.5% + $ZnSO_4$ 1.0%) followed by treatments T_9 ($FeSO_4$ 1.0% + $ZnSO_4$ 1.0%), T_5 ($ZnSO_4$ 1.0%) and T_6 ($FeSO_4$ 0.5% + $ZnSO_4$ 0.5%) when compared with T_1 (control) and other treatments. Zinc and iron possibly helps in greater assimilation of food material by the plant which resulted in greater dry matter production and leaf area which increased NAR. This might be the reason for increase in NAR in the present study.

Gowthami and Rao (2014) conducted field experiment to study the effect of foliar application of potassium, boron and zinc on growth analysis and seed yield in soybean. Results showed that foliar application of potassium nitrate @ 2 % + boric acid @ 50 ppm + zinc sulphate @ 1% at 30 and 60 DAS was found to be superior in increasing the NAR. Pise *et al.* (2019) found that foliar application of $ZnSO_4$ 0.5% + $FeSO_4$ 0.5% showed highest NAR followed by the foliar application of $ZnSO_4$ 0.5 % in lathyrus.

CGR (Crop Growth Rate)

The crop growth rate during 30-50, 50-70 and 70-90 DAS was found significant. CGR was significantly highest in treatment T_7 ($FeSO_4$ 0.5% + $ZnSO_4$ 1.0%) followed by treatments T_9 ($FeSO_4$ 1.0% + $ZnSO_4$ 1.0%), T_5 ($ZnSO_4$ 1.0%) and T_6 ($FeSO_4$ 0.5% + $ZnSO_4$ 0.5%) over T_1 (control). The application of ferrous sulphate and zinc sulphate enhances the dry matter production. CGR is the rate of dry matter production, hence increase in dry matter production enhanced CGR in the present investigation.

The result obtained was in accordance with the findings of Gowthami and Rao (2014). They found that treatment of potassium nitrate @ 2% + boric acid @ 50 ppm + zinc sulphate @ 1% when sprayed at 30 and 60 DAS increased the CGR in soybean.

In order to investigate Zn (116 ppm), Fe (116 ppm) and Zn+Fe foliar application effects on soybean Heidarian *et al.* (2011) conducted field experiment. They observed that application of zinc and iron combination treatment showed maximum CGR.

Yield $plot^{-1}$

Considering all treatments under study significantly highest seed yield $plot^{-1}$ was exhibited in treatment T_7 ($FeSO_4$ 0.5% + $ZnSO_4$ 1.0%) followed by treatments T_9 ($FeSO_4$ 1.0% + $ZnSO_4$ 1.0%), T_5 ($ZnSO_4$ 1.0%), T_6 ($FeSO_4$ 0.5% + $ZnSO_4$ 0.5%), T_8 ($FeSO_4$ 1.0% + $ZnSO_4$ 0.5%) and T_4 ($ZnSO_4$ 0.5%) when compared with T_1 (control) and rest of the treatments.

Seed yield is influenced by morpho-physiological parameters such as plant height, number of branches, number of leaves, leaf area and total dry matter production.All these parameters significantly enhanced by the application of iron and zinc alone or in combination. This might be the reason in increase in yield of safflower in the present investigation.

Previous investigation of Ravi *et al.* (2008) about seed yield of safflower were also coincided with our present findings, who declared that the treatment receiving 30 kg S ha^{-1} + Fe (0.5%) + Zn (0.5%) foliar spray recorded the highest yield in safflower. Galavi*et al.* (2012) concluded that the foliar application of Fe (4 ml l^{-1}) gave highest amount of

Table 1. Effect of foliar application of iron and zinc on plant height, number of primary branches plant^{-1}, number of secondary branches plant^{-1} number of leaves plant^{-1}, leaf area, leaf area index (LAI), total dry matter, days to 50% flowering and days to maturity in safflower

Treatments	Plant height (cm)	No. of primary branches plant^{-1}	No. of secondary branches plant^{-1}	No. of leaves plant^{-1}	Leaf area (dm^2)			Leaf area index (LAI)			Total dry natter(g)			Days to 50% flowering	Days to maturity (days)
	90 DAS	At harvest	At harvest	90 DAS	50 DAS	70 DAS	90 DAS	50 DAS	70 DAS	90 DAS	50 DAS	70 DAS	90 DAS	(days)	
T_1 (Control)	83.80	8.40	13.43	80.79	19.92	34.05	34.17	4.43	7.57	7.59	12.01	30.46	59.68	86.30	130.50
T_2 ($FeSO_4$ 0.5%)	88.70	9.30	15.30	85.75	22.99	37.21	37.57	5.11	8.28	8.35	12.87	35.83	62.81	88.60	131.60
T_3 ($FeSO_4$ 1.0%)	90.25	9.87	15.73	88.30	23.43	37.58	37.86	5.21	8.35	8.41	13.48	37.60	65.79	89.21	132.50
T_4 ($ZnSO_4$ 0.5%)	93.30	10.47	16.23	92.60	24.13	38.33	38.48	5.36	8.52	8.55	14.10	40.02	68.37	90.91	133.10
T_5 ($ZnSO_4$ 1.0%)	103.10	11.80	17.77	101.10	27.78	40.87	41.04	6.17	9.08	9.12	15.95	49.18	81.63	93.20	135.80
T_6 ($FeSO_4$ 0.5% + $ZnSO_4$ 0.5%)	99.80	11.53	17.37	97.98	26.47	39.41	39.87	5.88	8.76	8.86	15.08	46.29	78.75	92.80	134.46
T_7 ($FeSO_4$ 0.5% + $ZnSO_4$ 1.0%)	110.90	12.40	19.17	111.50	29.43	42.31	42.98	6.54	9.40	9.55	17.75	53.79	85.81	96.60	136.80
T_{8-} ($FeSO_4$ 1.0% + $ZnSO_4$ 0.5%)	95.20	11.07	16.93	95.90	25.91	38.82	38.96	5.76	8.64	8.66	14.81	43.37	74.12	91.50	133.90
T_9 ($FeSO_4$ 1.0% + $ZnSO_4$ 1.0%)	106.40	12.09	18.40	107.75	28.84	41.92	42.33	6.41	9.32	9.41	16.36	51.68	83.52	94.50	136.20
SE (m) ±	**5.18**	**0.63**	**1.03**	**5.69**	**1.57**	**1.52**	**1.56**	**0.35**	**0.34**	**0.26**	**0.94**	**2.77**	**4.69**	**1.56**	**1.04**
CD at 5 %	**15.53**	**1.88**	**3.08**	**17.05**	**4.70**	**4.55**	**4.67**	**1.04**	**1.01**	**0.77**	**2.81**	**8.31**	**14.07**	**4.67**	**3.11**

Table 2. Effect of foliar application of iron and zinc on RGR, NAR, CGR, seed yield plot^{-1} and harvest index in safflower

Treatments	Relative Growth Rate (g g^{-1} day^{-1})			Net Assimilation Rate (g/dm^2 day^{-1})			Crop Growth Rate (g m^{-2} day^{-1})			Seed yield plot^{-1}(kg)	Harvest index %
	30-50 DAS	50-70 DAS	70-90 DAS	30-50 DAS	50-70 DAS	70-90 DAS	30-50 DAS	50-70 DAS	70-90 DAS		
T_1 (Control)	0.0361	0.0465	0.0232	0.1148	0.1575	0.1622	6.867	20.500	29.978	1.047	28.50
T_2 ($FeSO_4$ 0.5%)	0.0389	0.0512	0.0240	0.1167	0.1748	0.1645	7.733	25.511	31.322	1.222	29.52
T_3 ($FeSO_4$ 1.0%)	0.0404	0.0513	0.0253	0.1327	0.1812	0.1661	8.689	26.800	31.500	1.238	29.94
T_4 ($ZnSO_4$ 0.5%)	0.0445	0.0522	0.0266	0.1358	0.1901	0.1682	8.944	28.800	32.467	1.280	31.10
T_5 ($ZnSO_4$ 1.0%)	0.0512	0.0561	0.0280	0.1546	0.2205	0.1783	11.356	36.922	35.578	1.352	35.80
T_6 ($FeSO_4$ 0.5% + $ZnSO_4$ 0.5%)	0.0455	0.0554	0.0275	0.1436	0.2160	0.1779	9.878	34.678	34.222	1.334	34.27
T_7 ($FeSO_4$ 0.5% + $ZnSO_4$ 1.0%)	0.0560	0.0575	0.0336	0.1773	0.2285	0.1927	13.167	40.044	36.067	1.437	38.42
T_{8} - ($FeSO_4$ 1.0% + $ZnSO_4$ 0.5%)	0.0448	0.0537	0.0268	0.1393	0.2012	0.1689	9.733	31.733	34.167	1.310	32.25
T_9 ($FeSO_4$ 1.0% + $ZnSO_4$ 1.0%)	0.0551	0.0563	0.0281	0.1632	0.2272	0.1842	12.244	39.244	36.056	1.391	36.92
SE (m) ±	**0.0028**	**0.0020**	**0.0014**	**0.0090**	**0.0123**	**0.0052**	**0.753**	**2.098**	**1.314**	**0.07**	**1.92**
CD at 5 %	**0.0084**	**0.0060**	**0.0042**	**0.0270**	**0.0369**	**0.0156**	**2.257**	**6.291**	**3.939**	**0.20**	**5.75**

seed yield followed by foliar application of Fe (4 ml l^{-1}) + B (2 ml l^{-1}) in safflower. Fattahi *et al.* (2018) conducted experiment and results suggested that application of nitrogen fertilizers along with nano-chelated zinc and iron improved safflower production under rainfed condition.

According to results of Pise *et al.* (2019), who studied the influence of zinc and iron on morpho-physiological parameters and yield of lathyrus (*Lathyrus sativus* L.) and stated that application of $ZnSO_4$ 0.5% + $FeSO_4$ 0.5% foliar spray at 25 and 40 DAS recorded highest grain yield with highest per cent increase in yield (58.82%) over control. Kumara *et al*. (2020) claimed that treatment receiving the foliar application of Grade-I multi micronutrient mixture (Fe-2%, Zn-3%, Mn-1% and B-0.5%) @ 10 ml l^{-1} at 30 and 50 DAS along with soil application of RDF and $ZnSO_4$ @ 6 kg ha^{-1} significantly enhanced seed yield in safflower.

Harvest Index

Among all treatments under study significantly more harvest index was exhibited in treatment T_7 ($FeSO_4$ 0.5% + $ZnSO_4$ 1.0%) followed by treatments T_9 ($FeSO_4$ 1.0% + $ZnSO_4$ 1.0%), T_5 ($ZnSO_4$ 1.0%) and T_6 ($FeSO_4$ 0.5% + $ZnSO_4$ 0.5%) when compared with control and rest of the treatments.

The significant effect of zinc and iron on harvest index was confirmed by Pise *et al.* (2019), who indicated that application of $ZnSO_4$ 0.5% + $FeSO_4$ 0.5% foliar spray significantly increased harvest index in lathyrus when compared with control. Kumara *et al*. (2020) recorded highest harvest index by the foliar application of Grade-I multi micronutrient mixture (Fe-2%, Zn-3%, Mn-1% and B-0.5%) @ 10 ml l^{-1} at 30 and 50 DAS.

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