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(54) **Kálium-szulfit/kálium-biszulfit (KS/KBS) alapú folyadék trágyaként**

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(54) **POTASSIUM SULFITE/POTASSIUM BISULFITE (KS/KBS) LIQUID AS FERTILIZERS**

KALIUMSULFIT-/KALIUMBISULFIT (KS/KBS) FLÜSSIGKEIT ALS DÜNGEMITTEL

LIQUIDE À BASE DE SULFITE DE POTASSIUM/BISULFITE DE POTASSIUM (KS/KBS) EN TANT QU'ENGRAIS

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EP 2 693 868 B1

Description

FIELD OF THE INVENTION

[0001] This invention relates to plant fertilizers that are useful in agriculture. Due to the increase in demand for agricultural productivity worldwide, the demand for fertilizers containing the primary plant nutrients nitrogen, phosphorous and potassium has increased.

BACKGROUND OF THE INVENTION

[0002] Mineral fertilizers are a cornerstone of modern day agriculture. Without them, worldwide production of all crops would be greatly reduced, placing a greater stress on our food supply system.

[0003] Fertilizers come in two basic forms, liquid and dry. In the U.S., over the last 50 years, liquid fertilizers have been gaining in popularity mainly due to the ease of handling and application.

[0004] For a liquid fertilizer to become a commercially viable product, it must have a fairly high nutrient analysis and must be able to blend with other liquid fertilizers to supply the required nutrients for a growing crop.

[0005] Urea ammonium nitrate (UAN) is a popular liquid fertilizer containing about 28 - 32% nitrogen. Ammonium polyphosphate (APP), another commonly used liquid fertilizer, contains from about 34 - 47% phosphate.

[0006] Sulfur (S) has emerged as a major nutrient for plants. It is considered the fourth major plant nutrient, after nitrogen, phosphorous and potassium, due to the amount required by plants. Sulfur is essential as a structural component of some amino acids found in both plants and animals, and is a part of the makeup of every living organism. Chlorophyll formation is also dependent on proper sulfur uptake.

[0007] About 10 million metric tons of sulfur-containing fertilizers are applied annually worldwide and have the potential to increase another 8 million tons. Applications of sulfur-containing fertilizers will increase even more due to the reduction in industrial sulfur dioxide emissions and the subsequent depletion of sulfur in the soil. In recent history, industrial sulfur dioxide emissions captured and transported by rainfall have been a significant source of sulfur for crop production, but environmental restrictions have reduced airborne SO_2 levels since the 1980's. Soil sulfur levels have become depleted with prolonged crop removal, sulfate leaching, low precipitation deposition, and declining soil organic matter.

[0008] Although sulfur exists in many different chemical forms, plants can only absorb sulfur through their root systems in the form of sulfate anion (SO_4^{-2}). Small amounts of sulfur dioxide gas can be absorbed through the plant's leaves, but the amount is too small to satisfy the plant's need.

[0009] There are two types of available sulfur-containing fertilizers for the crop application. The first type includes those fertilizers that are in the form of sulfate, which are ready for the plant's uptake. Examples of sulfate fertilizers are ammonium sulfate, sulfate of potash, and single superphosphate (SSP). These fertilizers may contain nitrogen (N), phosphorous (P), or potassium (K) as well, but they also are important due to sulfur (S) content. Sulfate fertilizers represent about 75% of the sulfur fertilizers applied annually.

[0010] The second type of sulfur-containing fertilizers are those materials containing sulfur in oxidation states of the sulfur other than sulfate, which need to go through chemical oxidation reaction to form the sulfate form which can be taken up by plants. Thiosulfate and elemental sulfur are examples of the second type. These forms of sulfur undergo chemical oxidation in the environment to convert to sulfate anion.

[0011] Another form of sulfur can exist as sulfite anion (SO_3^{-2}) or as bisulfite anion (HSO_3^{-1}). Potassium sulfite and potassium bisulfite are examples of sulfur in the sulfite or bisulfite forms. Potassium sulfite has been used as an anti-browning agent, an antioxidant and as a preservative. It is used as wine, beer, and fruit juice preservation. It is also used in fresh fruit and meat preservation. The preservative potassium sulfite is used as an E225 preservative. Both potassium bisulfite and potassium sulfite are used as photographic chemicals in film development.Australian patent specification AU-A1-38,324/78 discloses an agricultural process characterized by treating plants, seeds and/or soil with at least one salt selected from sodium sulfite, potassium sulfite, sodium pyrosulfite and potassium pyrosulfite.

[0012] In addition to being characterized according to their content and form, fertilizers are also characterized by how they are utilized in horticulture. For example, "starter fertilizer" is used to promote the growth of newly planted crops, particularly newly germinated seeds. Starter fertilizers are applied in low doses close to the plant seed to meet the demands of the seedling for nutrients until the plant's root system develops. They also enhance the development of the emerging seedling. Starter fertilizers are most beneficial when the crops are planted in cold and wet soil in the early spring or late fall. They are also used when the soil nutrients levels are low. In addition to N, P, and K, sulfur is a key component of the starter fertilizer.

[0013] To improve early season plant growth in cool soils, many crop producers band small amounts of starter fertilizers at planting. Applying fertilizer 2 inches to the side of the seed row and 2 inches below the seed row (2 X 2) or 2 inches to the side and on the surface (2 X 0) places the nutrients in a good position for root absorption. This has proven to be very effective for many crops, especially in minimum and no-tillage conditions where soils remain cooler for a longer period of time in the early spring.

[0014] To accomplish this, separate fertilizer openers are required to place the material in a 2 X 2 placement. This has a number of disadvantages such as cost, weight of the openers, residue clearance, planter space and soil disturbance which can adversely affect seed placement(1).

[0015] To avoid these problems, growers are placing fertilizers directly with the seed. This type of application is called a pop-up or in-furrow treatment. In-furrow treatments have proven to be agronomically as effective as 2 X 2 and 2 X 0 placements (2). However, there are several factors to consider that can have a negative effect on germination and/or seedling injury.

[0016] Crop sensitivity to fertilizer salts, cation exchange capacity (CEC) of the soil, soil type and moisture, organic matter, row spacing, and fertilizer band width are a few factors that must be considered in choosing the fertilizer and method for starter fertilization, along with the amount of risk a grower is willing to accept, including possible crop maturity delays(3).

[0017] Germination damage caused by fertilizers is primarily due to salt or osmotic effect, where fertilizer salts draw critical moisture from the seeds and soil surrounding the seeds. In some cases there is a toxic ion effect where certain ions can be toxic to germinating seeds, such as ammonia generated from urea hydrolysis. It is for this reason that university agricultural extension personnel do not recommend banding urea with the seed.

[0018] Many crops require side dressing to flourish properly. The term "top-dress" usually refers to broadcast applications on crops like small grains. The term "side dress" refers to fertilizer placed at relatively high amounts anywhere from three to four inches from the row to half way between the crop rows.

[0019] Plants absorb nutrients as well as other chemicals through their foliage to varying degrees. Growers in most all types of agriculture apply foliar nutritional sprays from time to time for various reasons. A basic philosophy many growers utilize is to apply what is believed to be required to the soil in the fertilization program, and use nutritional foliar supplements as a tool to give crops any nutrients they may still be lacking. Even though growers and researchers use this technique as a nutritional supplement, the mechanism of foliar absorption of nutrients is not well understood.

SUMMARY OF THE INVENTION

[0020] The present invention provides a new liquid fertilizer comprised of potassium sulfite and potassium bisulfite, with neutral to slightly alkaline pH, relatively lower salt index and potentially lower phytotoxicity damage compared to other sources of potassium and sulfur products applied in equal amounts as a starter fertilizer. More specifically, the present invention further relates to methods for fertilizing using a composition of potassium sulfite and potassium bisulfite, particularly as a starter fertilizer, in-furrow fertilizer, side dress fertilizer, and for foliar, broadcast, soil injection and fertigation applications. The fertilizer composition is comprised primarily of potassium sulfite (with the fertilizer grade of 0-0-23-8S).

[0021] Potassium sulfite (KS) solution is proposed as a starter product for in-furrow fertilizers. It was tested both in greenhouse experiments and field studies. Potassium sulfite was found to be about 6 to 9 times (v/v) less likely to burn the germinating seed than potassium thiosulfate, about 4 to 6 times safer than potassium sulfate, and about 10 to 22 times safer than potassium chloride. Potassium sulfite showed little to no phytotoxicity when applied at reasonable rates as foliar fertilizer. Potassium sulfite is a solution containing fairly high levels of potassium (P) and sulfur (S) with a low salt index and neutral/moderate pH range of 7.5-8.5.

DETAILED DESCRIPTION OF THE INVENTION

[0022] Tessenderlo Kerley Inc., Phoenix, Arizona produces a solution, referred to herein as "KS/KBS", of potassium sulfite (K_2SO_3) and potassium bisulfite ($KHSO_3$) at the highest pH allowable from sulfur dioxide and potassium hydroxide without co-absorption of CO_2 and at the highest concentration. Potassium sulfite is referred to as "KS", and potassium bisulfite is referred to as "KBS". The KS/KBS mixture is produced according to the following reaction pathways:

$$H_2S + 1.5O_2 \rightarrow SO_2 + H_2O$$

$$SO_2 + KOH \rightarrow KHSO_3$$

$$SO_2 + 2KOH \rightarrow K_2SO_3 + H_2O$$

[0023] The sulfur source for producing the composition of the invention is typically sulfur dioxide (SO_2) obtained from refinery off-gas, but may also be SO_2 obtained from other sources.

[0024] Alternatively, pure elemental sulfur may be used as the sulfur source, but usually will be more expensive than SO_2 obtained from refinery off-gas and does not provide the advantageous environmental benefit of recycling of waste gases. However, use of pure sulfur has the advantage that it will not give off carbonates when oxidized to form SO_2.

[0025] The KS/KBS is comprised mostly of potassium sulfite (KS) at pH about 8.3-8.5. The ratio of KS/KBS may be changed by changing the pH of the composition, as reflected in Table 1. Analysis of KS/KBS mixture ratios (parts KS to parts KBS) versus pH was performed in the lab which is pH dependent. The numbers in Table 1 shown in italics are the data points. The rest of the numbers are interpolated between data points.

Table 1. Analysis of KS/KBS Ratios vs. pH.

KS/KBS Ratio	pH	S/C Ratio (SO_2/K)	Bisulfite ($KHSO_3$)	Sulfite (K_2SO_3)
0.00[a]	*4.00*	1.0000	10.00	0.00
0.05[a]	4.91	0.9524	9.50	0.50
0.11[a]	*5.82*	0.9091	9.00	1.00
0.18[a]	6.04	0.8696	8.50	1.50
0.25[a]	*6.26*	0.8333	8.00	2.00
0.33[a]	6.42	0.8000	7.50	2.50
0.43[a]	*6.57*	0.7692	7.00	3.00
0.54[a]	6.70	0.7407	6.50	3.50
0.67[a]	*6.82*	0.7143	6.00	4.00
0.72[a]	6.86	0.7042	5.80	4.20
0.79[a]	6.90	0.6944	5.60	4.40
0.85[a]	6.93	0.6849	5.40	4.60
0.92[a]	6.97	0.6757	5.20	4.80
1.00[a]	*7.01*	0.6667	5.00	5.00
1.04[a]	7.03	0.6623	4.90	5.10
1.08[a]	7.04	0.6579	4.80	5.20
1.13[a]	7.06	0.6536	4.70	5.30
1.17[a]	7.07	0.6494	4.60	5.40
1.22[a]	7.09	0.6452	4.50	5.50
1.27[a]	7.11	0.6410	4.40	5.60
1.33[a]	7.12	0.6369	4.30	5.70
1.38[a]	7.14	0.6329	4.20	5.80
1.44[a]	7.15	0.6289	4.10	5.90
1.50[a]	*7.17*	0.6250	4.00	6.00
1.56[a]	7.20	0.6211	3.90	6.10
1.63[a]	7.23	0.6173	3.80	6.20
1.70[a]	7.25	0.6135	3.70	6.30
1.78[a]	7.28	0.6098	3.60	6.40
1.86[a]	7.31	0.6061	3.50	6.50
1.94[a]	7.34	0.6024	3.40	6.60
2.03[a]	7.37	0.5988	3.30	6.70
2.13[a]	7.39	0.5952	3.20	6.80
2.23[a]	7.42	0.5917	3.10	6.90
2.33[a]	7.45	0.5882	3.00	7.00

(continued)

KS/KBS Ratio	pH	S/C Ratio (SO_2/K)	Bisulfite ($KHSO_3$)	Sulfite (K_2SO_3)
2.45	7.47	0.5848	2.90	7.10
2.57	7.49	0.5814	2.80	7.20
2.70	7.51	0.5780	2.70	7.30
2.85	7.53	0.5747	2.60	7.40
3.00	7.56	0.5714	2.50	7.50
3.17	7.58	0.5682	2.40	7.60
3.35	7.60	0.5650	2.30	7.70
3.55	7.62	0.5618	2.20	7.80
3.76	7.64	0.5587	2.10	7.90
4.00	*7.66*	0.5556	2.00	8.00
4.13	7.69	0.5540	1.95	8.05
4.26	7.71	0.5525	1.90	8.10
4.41	7.74	0.5510	1.85	8.15
4.56	7.77	0.5495	1.80	8.20
4.71	7.80	0.5479	1.75	8.25
4.88	7.82	0.5464	1.70	8.30
5.06	7.85	0.5450	1.65	8.35
5.25	7.88	0.5435	1.60	8.40
5.45	7.90	0.5420	1.55	8.45
5.67	7.93	0.5405	1.50	8.50
5.90	7.96	0.5391	1.45	8.55
6.14	7.98	0.5376	1.40	8.60
6.41	8.01	0.5362	1.35	8.65
6.69	8.04	0.5348	1.30	8.70
7.00	8.07	0.5333	1.25	8.75
7.33	8.09	0.5319	1.20	8.80
7.70	8.12	0.5305	1.15	8.85
8.09	8.15	0.5291	1.10	8.90
8.52	8.17	0.5277	1.05	8.95
9.00	*8.20*	0.5263	1.00	9.00
9.53	8.29	0.5249	0.95	9.05
10.11	8.38	0.5236	0.90	9.10
10.76	8.47	0.5222	0.85	9.15
11.50[a]	8.56	0.5208	0.80	9.20
12.33[a]	8.65	0.5195	0.75	9.25
13.29[a]	8.74	0.5181	0.70	9.30
14.38[a]	8.83	0.5168	0.65	9.35
15.67[a]	8.92	0.5155	0.60	9.40

(continued)

KS/KBS Ratio	pH	S/C Ratio (SO_2/K)	Bisulfite ($KHSO_3$)	Sulfite (K_2SO_3)
17.18[a]	9.01	0.5141	0.55	9.45
19.00[a]	9.10	0.5128	0.50	9.50
21.22[a]	9.19	0.5115	0.45	9.55
24.00[a]	9.28	0.5102	0.40	9.60
27.57[a]	9.37	0.5089	0.35	9.65
32.33[a]	9.46	0.5076	0.30	9.70
39.00[a]	9.55	0.5063	0.25	9.75
49.00[a]	9.64	0.5051	0.20	9.80
66.57[a]	9.73	0.5037	0.15	9.85
101.04[a]	9.82	0.5025	0.10	9.90
207.33[a]	9.91	0.5012	0.05	9.95
999.00[a]	*10.00*	0.5003	0.01	9.99
[a]Comparative example				

[0026] The KS/KBS composition preferably contains low levels of carbonate. Carbonates are undesirable to be included in fertilizers.

[0027] The process for producing the KS/KBS solution of the present invention is performed at such a pH so as to avoid absorption of $CO_2$from refinery gas and from the SO_2 stream, to avoid the undesirable formation of potassium carbonate/bicarbonate in the KS/KBS solution. Formation of potassium carbonates is undesirable because it "ties up" the potassium, preventing it from forming potassium sulfite and potassium bisulfite. The higher the pH, the higher percentage of KS vs. percentage of KBS will be in the solution (see **Table 1**), however, the high pH has the detrimental effect of CO_2co-absorption from the gas stream. This will reduce the sulfur content in the solution, replacing it with carbon. Carbonate is undesirable in those fertilizers that are blended in low pH with each other due to froth formation. Also reflected in **Table 1** is the "S/C" ratio of the KS/KBS composition at varying pH levels. The S/C ratio reflects the ratio sulfite (S) to carbonate (C); the lower the S/C ratio, the higher will be the percentage of sulfur in the finished product.

[0028] In a preferred embodiment, the fertilizer composition will have a ratio of potassium to sulfur of 8:3.

[0029] In another preferred embodiment, the fertilizer composition will have a maximum amount of carbonate in the range of 0.5-1.0%.

[0030] The pH of the fertilizer composition may be adjusted (or the pH may vary based upon factors such as the process parameters by which it is produced). As the pH is adjusted, the ratio of KS to KBS changes accordingly. The composition of the invention may comprise from 1-100% KS/KBS (i.e., a mixture of KS and KBS), with the relative amounts of KS and KBS varying based on the pH of the composition.

[0031] A dry composition (without water) of the fertilizer composition may contain about 100% of KS/KBS.

[0032] In one embodiment, a solution in water of the fertilizer composition may contain about 35-45 wt. % KS/KBS.

[0033] In another embodiment, a solution in water of the fertilizer composition may contain about 35-41 wt. % KS/KBS.

[0034] In a preferred embodiment of the invention, the KS/KBS solution has a pH of about 8.5, and a total solution concentration of about 40 wt. % KS/KBS (mainly KS), about 17 wt. % SO_2, and up to about 0.5 wt. % sulfate as SO_4, with the remainder being water. Low levels of other impurities may be present (<0.5% carbonate). If refinery SO_2 gases are used, 0.1-1% of hydrocarbon impurities may accompany the product that could be removed by sparging with nitrogen or air. Higher levels of sulfate will be potassium sulfate (>0.5%), and will crystallize and precipitate out in solution that could be removed by filtration. Therefore, it is desirable to maintain levels of sulfate below about 0.5 wt. %. It is also preferable that production of the KS/KBS solution be carried out at a pH of about 8.5- 9.0 or more preferably at a lower pH of 8.2-8.6, to minimize the absorption of CO_2 from the SO_2 refinery off-gas.

[0035] KS is easy to handle, blends well with other liquid fertilizers, contains a fairly high level of potassium and sulfur (0-0-23-8S) and has a lower salt index than potassium thiosulfate (KTS) (salt index 46 vs. 64) with a pH between 7.5 and 8.5.

[0036] The amount of KS in the KS/KBS solution (% KBS) is in the range of about 1- 45 wt. %. In a preferred embodiment of the invention, the amount of KS is about 43-44 wt. % of the total liquid solution. If the liquid fertilizer solution is converted to a dry form, then amount of active material would be up to 100%, using careful drying to avoid the formation of potassium sulfate.

[0037] The present invention also relates to a method for fertilizing agricultural crops by applying a fertilizer comprised primarily of KS. More specifically, described herein is a method for using the fertilizer described herein as a starter fertilizer.

[0038] KS may be applied by a variety of methods, along with other fertilizers or pesticides or by itself, such as: as a starter or other fertilizer, as an in-furrow treatment, as a foliar fertilizer, as a side-dressed treatment after planting, as a preplant soil injected fertilizer, and for broadcast, soil-injection and fertigation applications.

[0039] KS is useful in no-tillage and minimal tillage conditions where it can be injected into the soil, surface dribbled in a band, sprayed between crop rows, or broadcast applied to meet the crops potassium and sulfur requirements. KS can be applied with herbicides to reduce the amount of trips over the field thus saving time, fuel and reducing soil compaction.

[0040] The fertilizer is useful in dry (non-irrigated) soil and in irrigated soil.

[0041] The fertilizer is beneficial for fertilizing all crops. Non-limiting examples of crops which may be treated with the fertilizer of the invention include barley, corn, cotton, sorghum, soybean, sugar beets, wheat, tomatoes and potatoes.

[0042] For example, in an embodiment of the invention, the fertilizer is used to enhance the germination of grain crops such as corn.

[0043] The fertilizer is applied at different rates (*i.e.,* amounts) depending upon the method of fertilization.

[0044] If the fertilizer is being applied directly next to the seed in a clay loam soil, then it should be applied at a rate of about 0.25 - 25 gal/acre. More preferably, it should be applied at a rate of about 1 -12 gal/acre. Still more preferably, it should be applied at a rate of about 1-8 gal/acre.

[0045] If the fertilizer is being applied directly next to the seed in a sandy soil, then it should be applied at a rate of about 0.12 - 15 gal/acre. More preferably, it should be applied to sandy soil at a rate of about 0.5 - 7.5 gal/acre. Still more preferably, it should be applied to sandy soil at a rate of about 0.5 - 4 gal/acre.

[0046] If the fertilizer is being applied 2 inches to the side of the seed row and 2 inches below the seed row (*i.e.,* 2 X 2 application) or 2 inches to the side of the seed on the surface, 2 X 0 or any other spacing close to the seed greater than 2 inches, then it should be applied at a rate of about 0.25 - 80 gal/acre. More preferably, in a 2 X 2, 2 X 0 or any other spacing close to the seed greater than 2 inches, application of fertilizer should be applied at a rate of about 1 - 40 gal/acre. Still more preferably, in a 2 X 2 application, 2 X 0 or any other spacing close to the seed greater than 2 inches, fertilizer should be applied at a rate of about 1-15 gal/acre.

[0047] If the fertilizer is being applied on the soil, regardless of what type of soil, away from the seed (greater than 2 inches), then it should be applied at a rate of about 1-80 gal/acre. More preferably, it should applied at a rate of about 1-60 gal/acre. Still more preferably, it should be applied at a rate of about 1 - 40 gal/acre.

[0048] If the fertilizer of the invention is being applied concurrently or immediately after or before another fertilizer, then the amount of the fertilizer of the invention should be adjusted. For example, if the KS fertilizer of the invention is applied with another fertilizer such as ammonium polyphosphate, APP (10-34-0 or 11-37-0), then the amount of KS fertilizer should be adjusted. Both KS and APP are salts, as are most fertilizers, and therefore there is a limit to how much of the fertilizer can be applied with the seed without harming the seed. The amount of KS should be reduced when applied with these or any fertilizer with the seed or near the seed because of accumulative effect from salt damage. For corn, growers apply from 1 to 5 gal/acre of APP 10-34-0 with the seed. If they apply KS in combination with the APP 10-34-0, then the rate of application of KS should not exceed 5 gallons/acre at the maximum rate of 10-34-0.

[0049] If soil conditions are dry, then growers should not apply KS with the seed, to avoid the possibility of desiccation of the seed. This is because KS, like most other fertilizers, is a salt, which would draw moisture away from and out of the seed, which is referred to as the salt effect of the fertilizer. A dry soil, in this case, would be one that does not have adequate moisture for good germination.

[0050] In a greenhouse study at South Dakota State University (SDSU), corn seeds were planted in a medium to fine textured soil with a CEC of 25 and adequate moisture. The objective of the study was to determine how much of an effect selected fertilizers have on seed germination. Several commonly used fertilizers were tested at different rates. Injury coefficients were developed from regression analysis for each fertilizer tested and are reported in Table 2. The higher the number, the greater the potential damage to germinating seeds. The approximate amount of fertilizer that can be placed with the seed was calculated by assuming a maximum amount of stand loss (percentage) allowed due to fertilizer placement.

<u>Example 1:</u>

[0051] Based on a maximum 4% stand loss due to fertilizer placement, the amount of 9-18-9 that can be placed with the corn seed on 30" rows is: 4 (percent stand loss) divided by the slope coefficient from **Table 1** for that fertilizer. In this case, the slope coefficient for 9-18-9 is 0.16.
4/0.16 = 25 lbs/acre of 9-18-9 applied in-furrow.

Example 2:

[0052] Fertilizer blends can be calculated using this data. If the desired rate of 10-34-0 is 4.0 gal/acre plus 1.0 gal/acre of KTS, the quantity of this blend that can be safely applied with the seed, given a maximum stand loss of 4%.

[0053] From **Table 2**, the injury coefficient for 10-34-0 is 0.057 and for KTS is 0.18. Multiply the gallons of material for each product by the coefficient for that product then add the results together and divide by 5.

10-34-0: 4 gal X 0.057	= 0.229
KTS: 1 gal X 0.18	= 0.180
Total = 0.409/5 =	0.082 (coefficient for blend)

Maximum rate of application for this blend is: 4/0.082 = 49 lbs/acre or approximately 4 gal/acre.

Example 3:

[0054] If the desired rate of 10-34-0 is 4 gal/acre plus 1.0 gal/acre of KS, the quantity of this blend that can be safely applied with the seed, given a maximum stand loss of 4%:

10-34-0: 4 gal X 0.057	= 0.229
KS: 1 gal X 0.02	= 0.02
Total = 0.249/5 =	0.05 (coefficient for blend)

[0055] Maximum rate of application of this blend: 4/ 0.05 = 80 lbs/acre or approximately 1.6 times more than the 10-34-0/KTS blend and 3.2 times more than the 9-18-9 blend.

[0056] When products were tested by themselves, KS was found to be on the order of 9 times (v/v) safer to germinating seed than KTS, 6 times safer than potassium sulfate and 22 times safer than potassium chloride. The SDSU study shows that no more than 28 pounds of KTS, 42 pounds of potassium sulfate and 11.4 pounds per acre of potassium chloride could be applied safely with the seed before germination was negatively affected, compared to 250 pounds per acre of KS. This is equivalent to approximately to 7 pounds per acre of K_2O for KTS, 21 pounds per acre of K_2O for potassium sulfate, 6.8 pounds per acre of K_2O for potassium chloride and 57 pounds per acre of K_2O for KS. Therefore, the amount of KS that can be safely applied with the seed is several times the amount of the other commonly used potassium based fertilizers and many more times what is needed for an in-furrow application.

[0057] A soybean germination trial was initiated near Jackson, Tennessee to test the results of the laboratory study. The study was conducted on a silt loam soil with a CEC of 7.5, pH of 6.6 and organic matter content of 1.4 percent. Soybeans were chosen because they are reported to be 6 times more sensitive to fertilizer salts than corn. Four rates of KS were applied to the seed as an in-furrow treatment: 0.0, 2.0, 5.0 and 10.0 gallons per acre. The study was replicated 3 times. Stand counts and phytotoxicity data were collected and reported in **Table 3.** There was no significant difference in plant populations between treated and untreated soybeans in this trial based on the number of soybean seedlings completely emerged. However, treatments 2 and 3 (2.0 and 5.0 gal/acre of KS) had the greatest number of emerged soybeans with 168 plants each per 30 feet of row, while the untreated check had the second lowest number of emerged soybeans with 155.7 plants per 30 feet of row. Treatment 4, the high rate of KS (10 gal/acre) had the lowest number of plants with 136.7 per 30 feet of row. This represents approximately 27 pounds of potassium applied directly in the seed furrow without any significant damage to germination. Soybeans are reported to be able to compensate as much as a 15% reduction in plant population without seriously affecting yield by increasing lateral branching and pods.

[0058] At the same location, a corn germination trial was established utilizing the same in-furrow KS treatments as the soybean study. Results are reported in **Table 4.** There was no significant difference between treatments using different rates of application of KS as to the number of corn seedlings per 30 feet of row. Readings were taken 10 days after treatments were applied. However, all of the KS treatments increased germination and stand count over the untreated check (48 plants), with the high rate of KS (10 gal/acre) having the greatest number of plants per 30 feet of row (65 plants), followed by the 5.0 gal/acre rate (60 plants) and then the 2 gal/acre rate (55 plants). No phytotoxicity was observed in any of the treatments. The high rate of KS increased the number of plants over the check by 35%.

[0059] A starter fertilizer trial on corn was established in southern Wisconsin near the town of Verona on a silt loam soil with a pH of 6.2, CEC of 11 and an organic matter of 2.3 percent. All the treatments were applied in-furrow at planting comparing KS against a standard application of KTS. All treatments, excluding the check plot, received 3 gal/acre of 10-34-0 along with the potassium treatments to make an N, P, K, and S blend. Results are reported in Table 5. All the potassium treatments increased the yield over the check and 10-34-0 treatment, but not enough to be significant at the

5% level. Treatment 7 (KS at 5.3 gal/acre) was the highest yielding at 180 bu/acre followed by treatments 5 and 6 (KS at 2.6 and 4.0 gal/acre) each at 177 bu/acre. The KTS treatment yielded 175.5 bu/ac, 8.5 bu/acre increases over the check plot and 16.4 bu/acre increases over the 10-34-0 treatment. There were no significant differences in plant populations across all treatments, even at the high rate of KS which had a combined rate of N + K in-furrow of 17.5 lbs/acre. This is well above the normal guidelines recommended by some universities of 8 to 10 lbs/acre of N + K that can be safely applied with the seed. Plant height and weight were positively affected by the potassium treatments with treatment 6 (KS at 4.0 gal/acre) having the tallest plants and the most weight, almost 7 inches taller than the check. However, there were no significant differences between the treatments for plant height or weight.

Foliar Application

[0060] Foliar fertilizers have been around for at least 50 years and are applied when soil conditions may be limiting crop growth due to temporarily unavailable and/or inadequate nutrient supply. KS was tested as a foliar application on corn and soybeans to determine phytotoxicity. Three treatments at 1.0, 2.0 and 3.0 gal/acre of KS along with 1.0 gal/acre of N-Sure® was applied to corn leaves and observed for phytotoxicity. N-Sure® is a liquid slow-release nitrogen fertilizer product that enhances foliar absorption of nutrients. Treatments were applied in the morning when the air temperature was approximately 80 degrees F, with 60 percent relative humidity. Afternoon temperatures on the same day of application reached 103 ° F, with a relative humidity of 40%. After 5 days, no phytotoxicity was observed in any of the treatments.

Sidedress Application

[0061] A greenhouse study was established to test the effect of high rates of KS on corn growth and development. The objective was to determine how much KS could be applied to corn before detrimental effects were observed. Three rates of KS: 20, 40 and 80 gal/acre were applied to young corn plants growing in ½ gallon containers. These treatments were compared to a check plot and 3 rates of KTS at the same volume of application: 20, 40 and 80 gal/acre. Each test treatment was replicated 6 times. The results are reported in **Table 6.** All of the treatments significantly increased the fresh weight of the corn over the check, except the high rate of KTS (80 gal/acre), which had the lowest fresh weight. The treatment with the greatest fresh weight was the 20 gal/acre of KTS followed by the 40 gal/acre of KS. There was no significant difference in plant height. The treatments with the tallest plants were the KS at 40 gal/acre with 34 inches of growth followed by the 20 and 40 gal/acre rates of KTS, both at 32.7 inches of growth. The untreated check had the least amount of growth at 22.3 inches.

Conclusion:

[0062] Laboratory studies and field trials have proven potassium sulfite (KS) to be an effective and safe source of potassium and sulfur for crop production. For in-furrow starter fertilizers, as well as 2 X 2 applications, the amount of potassium sulfite that can be safely applied with the seed is approximately 4 to 6 times more than potassium sulfate, and approximately 10 to 22 times more than potassium chloride on medium to fine textured soils. The ratio of potassium to sulfur in potassium sulfate is approximately the same as the ratio of potassium to sulfur in KS. A liquid fertilizer comprising or composed primarily of KS is readily absorbed into the soil thereby reducing the amount of free salt available that could be harmful to germination.

[0063] Using corn as an indicator crop, KS appears to be safe on foliage, especially when combined with N-Sure®, which improves coverage and absorption into the leaf.

[0064] Greenhouse study and on-going field trials indicate that KS is a safe and effective source of potassium and sulfur for crop production. KS can be easily mixed with liquid phosphate fertilizers like 10-34-0 or nitrogen fertilizers like UAN solution and injected into the soil, reducing potential loss of nutrients to erosion. KS can be an important source of potassium and sulfur for the liquid fertilizer industry.

Table 2. The Effect of Selected Fertilizers on Seed Germination

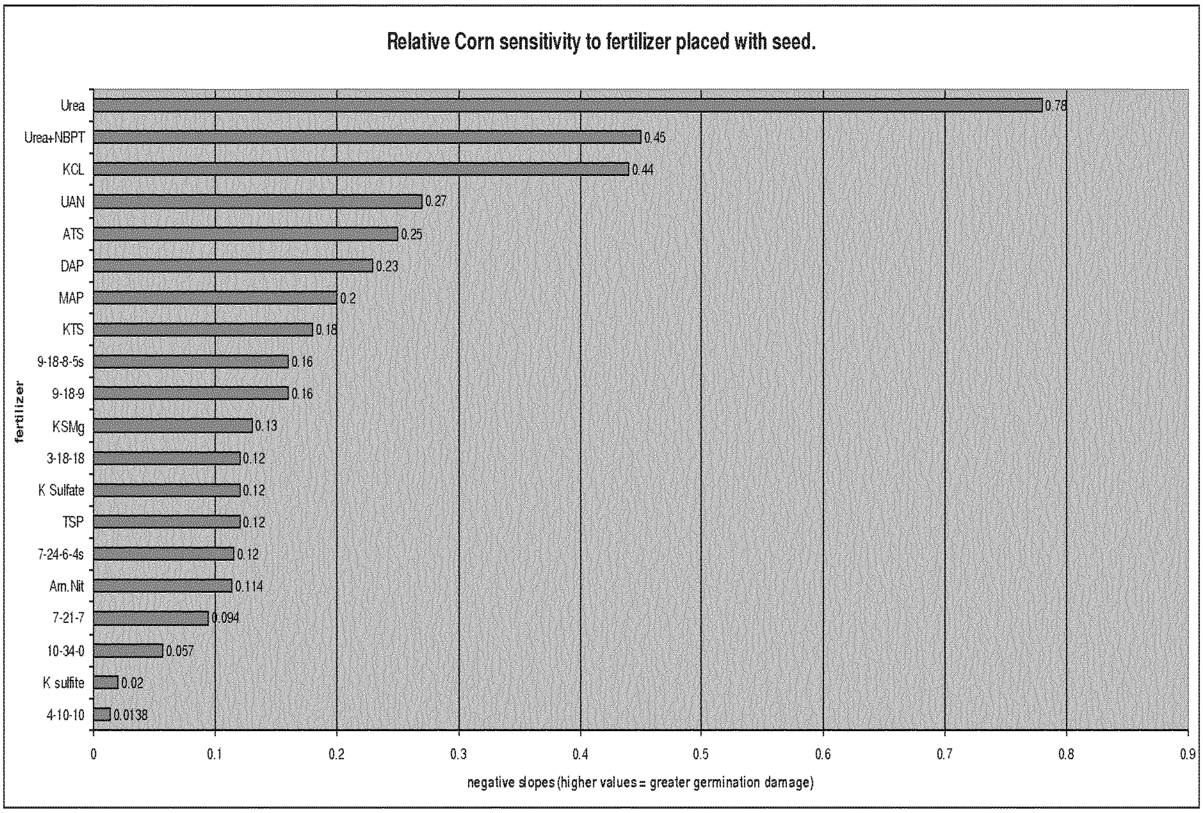

Table 3. The Effect of Potassium Sulfite as an In-Furrow Treatment on Soybean Emergence and Phytotoxicity

Treatment	Rate gal/acre	Soybean Emergence	% Phytotoxicity[(a)]
1.) Untreated Check	------------	155.7 a	0.0
2.) Potassium Sulfite	2.0	168.3 a	0.0
3.) Potassium Sulfite	5.0	168.0 a	0.0
4.) Potassium Sulfite	10.0	136.7 a	0.0
(a) = Percent phytotoxicity observed on seedlings 9 days after emergence.			

Table 4. The Effect of Potassium Sulfite on Corn Emergence and Phytotoxicity

Treatment	Rate gal/acre	Corn Emergence	% Phytotoxicity[(a)]
1.) Untreated Check	------------	48.0 a	0.0
2.) Potassium Sulfite	2.0	55.0 a	0.0
3.) Potassium Sulfite	5.0	60.0 a	0.0
4.) Potassium Sulfite	10.0	65.7 a	0.0
(a) = Percent phytotoxicity observed on seedlings 10 days after emergence.			

Table 5. The Effect of Potassium Sulfite Applied as an In-furrow Application on Corn.

Treatments	Rate/ac	Yield bu/ac	# Plants/ 60 ft row	Plant Ht inches	Plant Wt Lbs/12 plts
1.) Untreated Check	-----------	167.0	98	52.9	0.82
2.) 10-34-0	3.0 gal	159.1	98	52.3	0.90
3.) 10-34-0 + KTS	3.0 gal 1.0 gal	175.5	100	57.1	1.17
4.) 10-34-0 + KS	3.0 gal 1.3 gal	173.4	101	55.6	1.07
5.) 10-34-0 + KS	3.0 gal 2.6 gal	177.6	97	56.7	1.11
6.) 10-34-0 + KS	3.0 gal 4.0 gal	177.2	98	59.8	1.20
7.) 10-34-0 + KS	3.0 gal 5.3 gal	180.0	98	58.1	1.15

Table 6. Greenhouse Study on the Effects of KS on Corn Growth and Development.

Treatment		Fresh Wt	Dry Wt	Height (inches)
1.) Untreated Check		60.4 a	11.6 a	22.3
2.) KTS	20 gal	88.8 c	16.8 c	32.7
3.) KTS	40 gal	78.6 bc	15.2 bc	32.7
4.) KTS	80 gal	73.7 abc	14.4 abc	30.3
5.) KS	20 gal	79.3 bc	15.8 bc	28.3
6.) KS	40 gal	83.3 bc	16.2 bc	34.0
7.) KS	80 gal	79.7 bc	13.5 ab	30.0

(1) Gelderman, Dr. Ron, S.D.S.U., Fertilizer Placement with Seed - A Decision Aid, March 2007.
(2) Gordon, B. 1999. Effects of Placement, Rate, and Source of Starter Fertilizer Containing Potassium on Corn and Soybean Production. Kansas Fertilizer Research. Report 847. KSU, Manhattan, KS.
(3) Harapiak, J.T., N.A. Flore. 1995. Fertilizer Nitrogen Management Options. Proc. WCFA Agronomy Workshop. Red Deer, AB, Canada.
(4) Conversations with Dr. Ron Gelderman, South Dakota State University Soil Testing Laboratory.

Claims

1. A liquid fertilizer composition comprising 1 to 90 wt.% potassium sulfite and potassium bisulfite in water at a pH of 7.5 to 8.5.

2. Fertilizer composition of claim 1, comprising 35-45 wt. % potassium sulfite and potassium bisulfite, preferably comprising 35-41 wt. % potassium sulfite and potassium bisulfite, more preferably comprising 40 wt. % potassium sulfite and potassium bisulfite.

3. Fertilizer composition according to any of claims 1 or 2, comprising up to 0.5 wt. % SO_4.

4. Fertilizer composition according to any of claims 1 to 3, comprising a maximum amount of carbonate in the range of 0.5-1.0 wt. %.

5. Fertilizer composition according to any of claims 1 to 4, having a salt index of 46 and/or having a ratio of potassium to sulfur of 8:3.

6. Fertilizer composition according to any of claims 1 to 5, having a pH of 8.5, and having a total solution concentration of 40 wt. % KS/KBS, and up to 0.5 wt. % sulfate, and a remainder being water.

7. Method for fertilizing agricultural crops wherein the fertilizer composition according to any of claims 1 to 6 is applied simultaneously with, prior to or immediately after planting seed for the crop.

8. Method of claim 7 wherein the method for applying fertilizer composition is selected from the group consisting of in-furrow application, foliar application, side-dress treatment after planting, pre-planting soil injection, broadcast application and fertigation.

9. Method according to any of claims 7 or 8 wherein the crop is selected from the group consisting of barley, corn, cotton, sorghum, soybeans, sugar beets, wheat, tomatoes and potatoes.

10. Method of claim 9,

- wherein the fertilizer composition is applied next to the seed in a clay loam soil at a rate of 0.2-23.4 mL/m^2 (0.25-25 gallons/acre), preferably at a rate of 0.9-11.2 mL/m^2 (1-12 gallons/acre), more preferably at a rate of 0.9-7.5 mL/m^2 (1-8 gallons/acre), or
- wherein the fertilizer composition is applied next to the seed in a sandy soil at a rate of 0.1-14.0 mL/m^2 (0.12-15 gallons/acre), preferably at a rate of 0.5-7.0 mL/m^2 (0.5-7.5 gallons/acre), more preferably at a rate of 0.5-3.7 mL/m^2 (0.5-4 gallons/acre), or
- wherein the fertilizer composition is applied to a side of a seed row and below the seed row, at a rate of 0.2-74.8 mL/m^2 (0.25-80 gallons/acre), preferably at a rate of 0.9-37.4 mL/m^2 (1-40 gallons/acre), more preferably at a rate of 0.9-14.0 mL/m^2 (1-15 gallons/acre), or
- wherein the fertilizer composition is applied on soil away from the seed at a rate of 0.9-74.8 mL/m^2 (1-80 gallons/acre), preferably at a rate of 0.9-56.1 mL/m^2 (1-60 gallons/acre), more preferably at a rate of 0.9-37.4 mL/m^2 (1-40 gallons/acre).

Patentansprüche

1. Eine flüssige Düngemittelzusammensetzung umfassend 1 bis 90 Gew.-% Kaliumsulfit und Kaliumbisulfit in Wasser bei einem pH von 7,5 bis 8,5.

2. Düngemittelzusammensetzung von Anspruch 1, umfassend 35-45 Gew.-% Kaliumsulfit und Kaliumbisulfit, vorzugsweise umfassend 35-41 Gew.-% Kaliumsulfit und Kaliumbisulfit, besonders bevorzugt 40 Gew.-% Kaliumsulfit und Kaliumbisulfit.

3. Düngemittelzusammensetzung nach einem der Ansprüche 1 oder 2, umfassend bis zu 0,5 Gew.-% SO_4.

4. Düngemittelzusammensetzung nach einem der Ansprüche 1 bis 3, umfassend eine maximale Menge an Karbonat im Bereich von 0,5-1,0 Gew.-%.

5. Düngemittelzusammensetzung nach einem der Ansprüche 1 bis 4, mit einem Salzindex von 46 und/oder mit einem Verhältnis von Kalium zu Schwefel von 8:3.

6. Düngemittelzusammensetzung nach einem der Ansprüche 1 bis 5, mit einem pH von 8,5, und mit einer Gesamtlösungskonzentration von 40 Gew.-% KS/KBS, und bis zu 0,5 Gew.-% Sulfat, und ein Rest ist Wasser.

7. Verfahren zur Düngung landwirtschaftlicher Kulturpflanzen, bei dem die Düngemittelzusammensetzung nach einem der Ansprüche 1 bis 6 gleichzeitig mit, vor oder unmittelbar nach dem Anpflanzen von Saatgut für die Kulturpflanze angewendet wird.

8. Verfahren nach Anspruch 7, wobei das Verfahren zur Anwendung von Düngemittelzusammensetzung aus der Gruppe bestehend aus Applikation in der Furche, Blattanwendung, Reihendüngungbehandlung nach dem Anpflanzen, Bodeninjektion bei Vorpflanzung, der breitflächigen Anwendung und Fertigation ausgewählt ist.

9. Verfahren nach einem der Ansprüche 7 oder 8, wobei die Kulturpflanze aus der Gruppe bestehend aus Gerste,

Mais, Baumwolle, Sorghum, Sojabohnen, Zuckerrüben, Weizen, Tomaten und Kartoffeln ausgewählt ist.

10. Verfahren von Anspruch 9,

- wobei die Düngemittelzusammensetzung neben dem Saatgut in einem Lehm-Ton-Boden mit einer Rate von 0,2-23,4 mL/m^2 (0,25-25 Gallonen/Morgen), vorzugsweise mit einer Rate von 0,9-11,2 mL/m^2 (1-12 Gallonen/Morgen), bevorzugter mit einer Rate von 0,9-7,5 mL/m^2 (1-8 Gallonen/Morgen) ausgebracht wird, oder
- wobei die Düngemittelzusammensetzung neben dem Saatgut in einem sandigen Boden mit einer Rate von 0,1-14,0 mL/m^2 (0,12-15 Gallonen/Morgen), vorzugsweise mit einer Rate von 0,5-7,0 mL/m^2 (0,5-7,5 Gallonen/Morgen), bevorzugter mit einer Rate von 0,5-3,7 mL/m^2 (0,5-4 Gallonen/Morgen) ausgebracht wird, oder
- wobei die Düngemittelzusammensetzung auf eine Seite einer Saatreihe und unterhalb der Saatreihen mit einer Rate von 0,2-74,8 mL/m^2 (0,25-80 Gallonen/Morgen), vorzugsweise mit einer Rate von 0,9-37,4 mL/m^2 (1-40 Gallonen/Morgen), bevorzugter mit einer Rate von 0,9-14,0 mL/m^2 (1-15 Gallonen/Morgen), ausgebracht wird, oder
- wobei die Düngemittelzusammensetzung auf den Boden weg von dem Saatgut mit einer Rate von 0,9-74,8 mL/m^2 (1-80 Gallonen/Morgen), vorzugsweise mit einer Rate von 0,9-56,1 mL/m^2 (1-60 Gallonen/Morgen), bevorzugter mit einer Rate von 0,9-37,4 mL/m^2 (1-40 Gallonen/Morgen) ausgebracht wird.

Revendications

1. Une composition d'engrais liquide comprenant 1 à 90% en poids de sulfite de potassium et de bisulfite de potassium dans l'eau à un pH de 7,5 à 8,5.

2. Composition d'engrais de la revendication 1, comprenant 35-45% en poids de sulfite de potassium et de bisulfite de potassium, comprenant de préférence 35-41% en poids de sulfite de potassium et de bisulfite de potassium, plus préférentiellement 40% en poids de sulfite de potassium et de bisulfite de potassium.

3. Composition d'engrais selon l'une quelconque des revendications 1 ou 2, comprenant jusqu'à 0,5% en poids de SO_4.

4. Composition d'engrais selon l'une quelconque des revendications 1 à 3, comprenant une quantité maximale de carbonate dans la plage de 0,5-1,0% en poids.

5. Composition d'engrais selon l'une quelconque des revendications 1 à 4, ayant un indice de salinité de 46 et/ou ayant un rapport de potassium au soufre de 8:3.

6. Composition d'engrais selon l'une quelconque des revendications 1 à 5, ayant un pH de 8,5, et ayant une concentration totale de la solution de 40% en poids KS/KBS, et jusqu'à 0,5% en poids de sulfate, et un reste étant de l'eau.

7. Procédé pour la fertilisation de cultures agricoles dans lequel la composition d'engrais selon l'une quelconque des revendications 1 à 6 est appliquée simultanément avec, avant ou immédiatement après la plantation de semence pour la culture.

8. Procédé de la revendication 7, dans lequel le procédé pour l'application d'une composition d'engrais est choisi parmi le groupe consistant en l'application dans les sillons, l'application foliaire, le traitement latéral de l'épandage après la plantation, l'injection dans le sol pour la préplantation, l'application en pleine surface et la fertirrigation.

9. Procédé selon l'une quelconque des revendications 7 ou 8, dans lequel la culture est choisie parmi le groupe constitué par l'orge, le maïs, le coton, le sorgho, le soja, la betterave à sucre, le blé, les tomates et les pommes de terre.

10. Procédé de la revendication 9,

- dans lequel la composition d'engrais est appliquée à côté de la semence dans un sol loam argileux à une dose de 0,2-23,4 mL/m^2 (0,25-25 gallons/acre), de préférence à une dose de 0,9-11,2 mL/m^2 (1-12 gallons/acre), plus préférablement à une dose de 0,9-7,5 mL/m^2 (1-8 gallons/acre), ou
- dans lequel la composition d'engrais est appliquée à côté de la semence dans un sol sablonneux à une dose de 0,1-14,0 mL/m^2 (0,12-15 gallons/acre), de préférence à une dose de 0,5-7,0 mL/m^2 (0,5-7,5 gallons/acre), plus préférablement à une dose de 0,5-3,7 mL/m^2 (0,5-4 gallons/acre), ou

- dans lequel la composition d'engrais est appliquée sur un côté d'une rangée de semences et au-dessous de la rangée de semences, à une dose de 0,2-74,8 mL/m^2 (0.25-80 gallons/acre), de préférence à une dose de 0,9-37,4 mL/m^2 (1-40 gallons/acre), plus préférablement à une dose de 0,9-14,0 mL/m^2 (1-15 gallons/acre), ou
- dans laquelle la composition d'engrais est appliquée sur le sol loin de la semence à une dose de 0,9-74,8 mL/m^2 (1-80 gallons/acre), de préférence à une dose de 0,9-56,1 mL/m^2 (1-60 gallons/acre), plus préférablement à une dose de 0,9-37,4 mL/m^2 (1-40 gallons/acre).

REFERENCES CITED IN THE DESCRIPTION

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- **GORDON, B.** Effects of Placement, Rate, and Source of Starter Fertilizer Containing Potassium on Corn and Soybean Production. Kansas Fertilizer Research, 1999 **[0064]**
- Fertilizer Nitrogen Management Options. **HARAPIAK, J.T. ; N.A. FLORE.** Proc. WCFA Agronomy Workshop. Red Deer, 1995 **[0064]**

Szabadalmi igénypontok

1. Folyékony trágyakészítmény, amely 1 - 90 tömeg% kálium-szulfitot és kálium-biszulfitot tartalmaz vízben pH 7,5 - 8,5 értéknél.

2. Az 1. igénypont szerinti trágyakészítmény, amely 35-45 tömeg% kálium-szulfitot és kálium-biszulfitot, előnyösen 35-41 tömeg% kálium-szulfitot és kálium-biszulfitot, előnyösebben 40 tömeg% kálium-szulfitot és kálium-biszulfitot tartalmaz.

3. Az 1. vagy 2. igénypont szerinti trágyakészítmény, amely 0,5 tömeg%-ig terjedően SO_4-et tartalmaz.

4. Az 1-3. igénypontok bármelyike szerinti trágyakészítmény, amely karbonátot maximálisan a 0,5-1,0 tömeg% tartományban tartalmaz.

5. Az 1-4. igénypontok bármelyike szerinti trágyakészítmény, amelynek sóindexe 46 és/vagy ahol a kálium kénhez viszonyított aránya 8:3.

6. Az 1-5. igénypontok bármelyike szerinti trágyakészítmény, amelynek pH-ja 8,5, és 40 tömeg% KS/KBS a teljes oldat koncentráció, és 0,5 tömeg%-ig terjedően szulfátot tartalmaz, és a maradék víz.

7. Eljárás mezőgazdasági termény állomány trágyázására, ahol az 1-6. igénypontok bármelyike szerinti trágyakészítményt a termény magjának elültetésével egyidőben, azt megelőzően vagy közvetlenül utána alkalmazzuk.

8. A 7. igénypont szerinti eljárás, ahol a trágyakészítmény alkalmazásának eljárását az alábbiakból álló csoportból választjuk: barázdában történő alkalmazás, levélen történő alkalmazás, sortrágyázás ültetés után, ültetés előtti talaj injekciózás, trágyaszórás és tápoldatozás.

9. A 7. vagy 8. igénypont szerinti eljárás, ahol a terményt az alábbiakból álló csoportból választjuk: árpa, kukorica, gyapot, cirok, szója, cukorrépa, búza, paradicsom és burgonya.

10. A 9. igénypont szerinti eljárás,

- ahol a trágyakészítményt a vetést követően agyagos iszapos termőföldre alkalmazzuk 0,2-23,4 mL/m^2 (0,25-25 gallon/hold) arányban, előnyösen 0,9-11,2 mL/m^2 (1-12 gallon/hold) arányban, előnyösebben 0,9-7,5 mL/m^2 (1-8 gallon/hold) arányban, vagy
- ahol a trágyakészítményt a vetést követően homokos talajra alkalmazzuk 0,1-14,0 mL/m^2 (0.12-15 gallon/hold) arányban, előnyösen 0,5-7,0 mL/m^2 (0,5-7,5 gallon/hold) arányban, előnyösebben 0,5-3,7 mL/m^2 (0,5-4 gallon/hold) arányban, vagy
- ahol a trágyakészítményt a vetési sor mellett és a vetési sor alatt alkalmazzuk 0,2-74,8 mL/m^2 (0,25-80 gallon/hold) arányban, előnyösen 0,9-37,4 mL/m^2 (1-40 gallon/hold) arányban, előnyösebben 0,9-14,0 mL/m^2 (1-15 gallon/hold) arányban, vagy

- ahol a trágyakészítményt a talajra a vetéstől távol alkalmazzuk 0,9-74,8 mL/m^2 (1-80 gallon/hold) arányban, előnyösen 0,9-56,1 mL/m^2 (1-60 gallon/hold) arányban, előnyösebben 0,9-37,4 mL/m^2 (1-40 gallon/hold) arányban.